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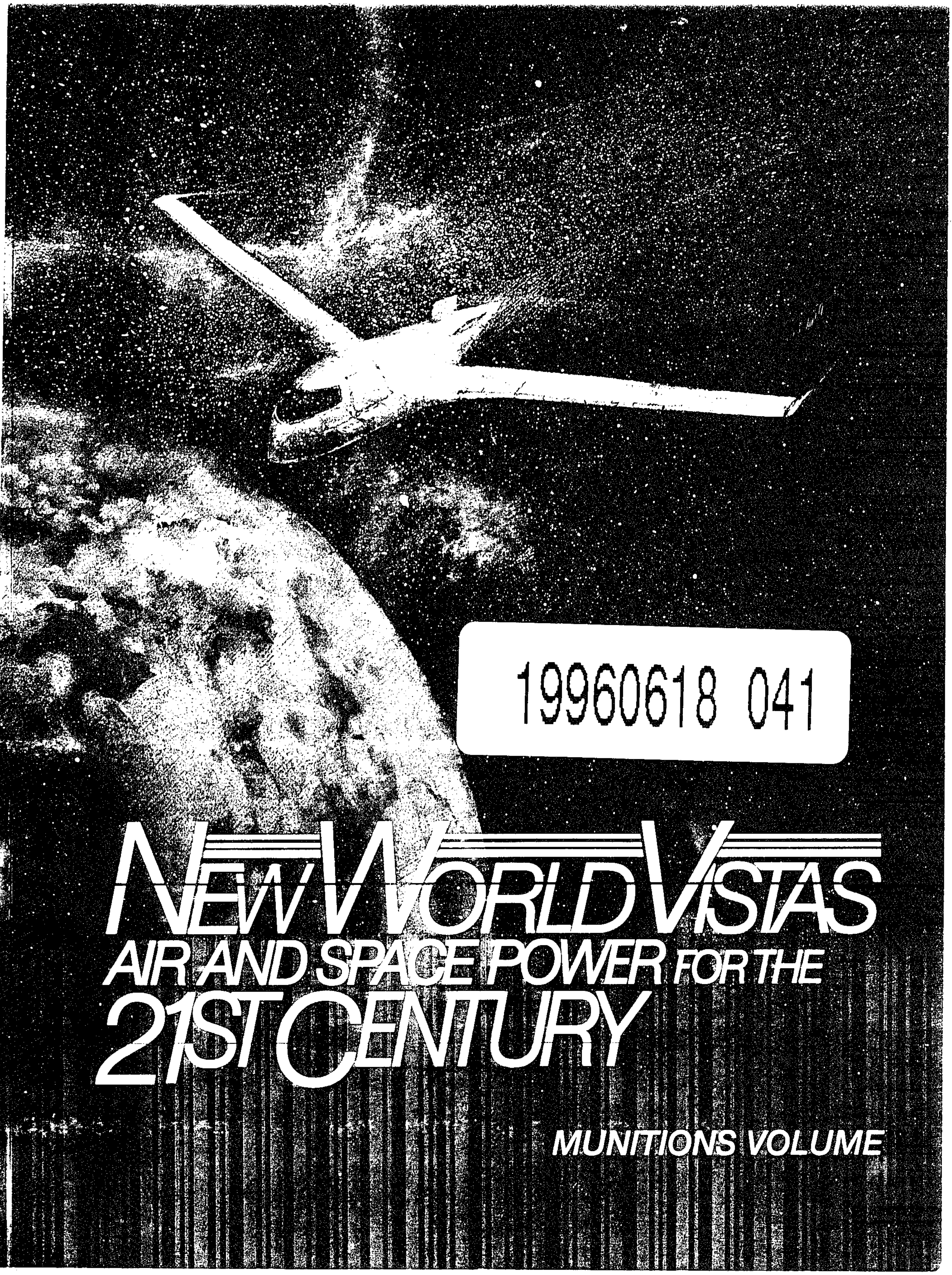

NEW WORLD VISTAS
AIR AND SPACE POWER FOR THE 21ST CENTURY

MUNITIONS VOLUME

NEW WORLD VISTAS

AIR AND SPACE POWER FOR THE 21ST CENTURY

MUNITIONS VOLUME

This report is a forecast of a potential future for the Air Force. This forecast does not necessarily imply future officially sanctioned programs, planning or policy.

Abstract

The Munitions Panel identified several high payoff munition concepts that address recognized, future U.S. defense needs. The concepts are achievable within the next 10-30 years and will significantly enhance the warfighting capabilities of the U.S. Air Force. In general, we focused on smaller, lighter, agile, more lethal, and more affordable weapons that can enhance Air Force munitions and the target strike capability of the delivery platform. Some of the enabling technologies are here, others are just around the corner, and certain key ones await fundamental breakthroughs in materials or processes. But combined with creative approaches to weaponry design, all offer crucial enhancements to the Air Force warfighting capabilities. The Munitions Panel recommendations will effectively exploit and implement the high pay off munitions concepts identified to address projected U.S. defense needs. Among the capability needs cited and weapon concepts identified are:

Theater Ballistic Missile Defense	Airborne Ballistic Interceptor
Negate Enemy C^3I	Cruise Missile to Incapacitate Enemy Electronics
Aircraft Self Defense	Self Protection Missile
Stop Invading Armies	Miniature Autonomous Munitions

Executive Summary

Introduction

The Munitions Panel has identified several high payoff munition concepts that address recognized, future U.S. defense needs. The concepts are achievable within the next 10-30 years and will significantly enhance the warfighting capabilities of the U.S. Air Force. In general, we focused on smaller, lighter, agile, more lethal, and more affordable weapons that can enhance Air Force munitions and the target strike capability of the delivery platform. We have divided our prioritized list of nine "Capability Needs and Weapons Concepts" so as to address them in two groups. The first group lists four needs and concepts that are discussed in more detail in the Panel's executive summary. Both lists are described in the body of the report. The lists are shown below:

First List

Capability Needs	Weapon Concepts
Theater Ballistic Missile Defense	Airborne Ballistic Missile Interceptor
Negate Enemy C^3I	ECM Attack Cruise Missile
Aircraft Self Defense	Self Protect Missile (KKV, HE, or ECM)
Stop Invading Armies	Autonomous Miniature Munitions

Second List

Capability Needs	Weapon Concepts
LO Cruise Missile Defense	Air Borne Interceptor (KKV, HE, or ECM)
Attack Deeply Buried Hard Targets	Hard Target Munitions Robotic Micro Munitions
Retain Air-to-Air Combat Edge	Small, Agile Air-to-Air Missile
5 Minute Attack	Hypersonic Missile
Attack WMD on the Ground	Precision Thermoflux Weapon

Discussion of the First List

During the next two decades, many countries will obtain very high technology systems such as ballistic missiles, low observable cruise missiles, highly effective air-to-air missiles, more modern and mobile armies, as well as more sophisticated information, sensor and communication systems. Assessing the highest priority critical capability needs and robust weapon concepts as solutions led to the first list.

First, a high velocity Airborne Interceptor (ABI) missile system can be built today that could effectively intercept theater ballistic missiles during their boost/ascent phase. The Air Force Scientific Advisory Board (SAB) has shown that full 360° azimuthal coverage from a single aircraft is easily obtained, thus reducing by a factor of two the required number of aircraft on patrol from the number used in previous Cost Effectiveness Analyses (COEAs). This could be especially important for Uninhabited Combat Air Vehicles (UCAVs) or Unmanned Air Vehicles (UAVs) where wingmen are not required. The acquisition system can be installed in a pod which provides flexibility to the wing commander for aircraft assignment. This missile could also be the basis for other high velocity weapons that would dramatically increase the attack reach from an airplane or an UCAV. It also has the potential to be expanded into a national missile defense capability. An ABI could be developed in partnership with both the U.S. Navy and NATO allies in a joint program.

Second, the increasing dependence of potential enemy armies, navies, and air forces on electronic systems for sensing, data processing, communication, and command and control make the nodes in these systems prime, high value targets. A stealthy cruise missile could be designed with effective Electronic Countermeasure (ECM) technology to shut down these targets.

Third, self-protection of aircraft demands that new concepts be developed and integrated to provide the capability to intercept enemy air-to-air and surface-to-air missiles in fighter, bomber and transport aircraft. A Self Protect Missile (SPM) with several possible warheads is proposed.

Fourth, the development of autonomous miniaturized munitions will significantly enhance Air Force interdiction, and "stop invading armies". Small, light weight, high lethality, and autonomous munitions with great precision will increase the "pace" of tactical warfare and multiply "kills" per sortie. These munitions' ability to quickly adapt to a wide spectrum of target types will be a major asset in the implementation of dynamic battlefield management concepts.

Each of the above four concepts are discussed in separate sections below.

Defeat Theater Ballistic Missiles

Introduction

The U.S. has an urgent and critical need to defeat ballistic missiles. One of the most effective kill approaches is to physically destroy the missile in its early ascent phase. The mobility of the airplane can be exploited by the U.S. Air Force in ballistic missile defense provided the airplane can launch an interceptor missile with the necessary capabilities for destroying the enemy missile during boost or (at a minimum) before the target has dispensed submunitions. The key

requirements for such an interceptor are target acquisition capability, high speed flight, and intercept guidance.

Concept

Our recommended approach is an ABI missile which is launched from a fighter, bomber or uninhabited aircraft with a stand-off range of 1200km against Theater Ballistic Missiles (TBM) with unitary warheads, and other time critical ballistic missiles. TBMs with submunitions could be destroyed prior to submunition dispension from a stand-off range of 300 to 450km, which is comparable to the Airborne Laser (ABL). This kinetic energy missile will have a velocity of about 5km/second and have a hit to kill probability of about 80%. It is important to recognize that the TBM warhead is physically destroyed at intercept, thus terminating the TBM mission at that instant. Shortfall of an intact nuclear, biological or chemical warhead no longer is an issue as it is with the ABL. All of the technology required to deliver this missile system exists today. It would be a significant complementary technology to the ABL for direct destruction of ballistic missile warheads before they fractionate into separate submunitions. The ABI represents the current lowest technical risk and can be fielded in ten years or less. Launch platforms to deliver the ABI exist in the current force structure. In addition, UAVs such as the Tier II Plus and Tier III Minus ACTD programs with their long loiter time at high altitude are extremely attractive as ABI launch aircraft. The ABI's key advantages are: a 2:1 velocity advantage over the threat missile; physical destruction of the threat missile warhead; and an all-weather capability. The potential is large for such a system to significantly enhance the U.S. Air Force posture for putting a lid on rogue nations.

Robust target acquisition is available from an Infrared Search and Track or Laser Radar (IRST/LADAR) on-board the aircraft which will detect the theater ballistic missile launch. The second key enabling technology is a solid rocket system, correctly sized, to provide the necessary velocity. No new rocket technology is needed for the interceptor missile itself. Building a missile with the optimum delta-V to exploit the Ballistic Missile Defense Office's Kinetic Kill Vehicle (KKV) hardware would give the U.S. a sufficient system.

Intercept guidance has been demonstrated in closing-velocity tests such as the successful intercept of a test fired Inter Continental Ballistic Missile (ICBM) in the Homing Overlay Experiment at 10km/second and in the High Endoatmospheric Defense Interceptor (HEDI) demonstration of sensor window cooling and tracking accuracy. This was also demonstrated in the Extended Range Interceptor (ERINT) for the Patriot System Upgrade (PAC-III) and the Stinger ground to air missile. These systems have time constants of 10 to 80 ms, which are consistent with their respective closing speeds to obtain hit distributions within a 25 cm radius circle of the preferred lethal hit point. We anticipate the development of lethality enhancers that will rip open all chemical/biological canisters for destruction over a rogue nation at stand-off ranges of 300 to 450 kilometers.

Prevent Enemy Electronic Operations Using ECM Attack Cruise Missile

Introduction

Conducting military operations is increasingly dependent on electronic systems. Information collectors, processors, distributors, sensors, weapons, and Command, Control, Communications, Computers and Information (C^4I) systems comprise a large set of very high value targets that are vulnerable to damage by electronic countermeasures. Over the past decade, these technologies have been sufficiently developed (in both the U.S. and abroad) to consider practical development of weapons that employ these technologies. While such systems could be utilized from an aircraft directly, the use of a missile lowers the requirements and risks because considerably lower levels of power can be effective at shorter ranges to the target and it also reduces fratracide concerns.

Concept

A specific Electronic Countermeasure concept is described in detail in the classified New World Vistas report. (See the section on Munitions Panel Concept.)

Regaining Aircraft Survival With the Self Protect Missile (SPM)

Introduction

Our fighters, bombers, airlift aircraft, surveillance, and command and control aircraft are seriously threatened by modern highly lethal air and surface launched missiles. These missiles are very difficult to countermeasure (with, for example, IR Focal Plane Arrays) and are proliferating around the world. Aircraft, sensors, countermeasures and active self-defense must be improved for aircraft to successfully conduct missions in the future. This section describes a Self-Protect Missile (SPM) concept that capitalizes on very recent developments and demonstrations in propulsion, reaction controls, and warheads to counter adversary air-intercept missile capabilities.

SPM Concept

The proposed SPM would employ an "area kill" warhead such as an Electronic Countermeasure (ECM) or directional HE/fragmentation warhead on a modern reaction-controlled vehicle. The weapon could be either a snap-turn forward launch missile or a pure reaction controlled vehicle similar to the Lightweight Exoatmospheric Projectile (LEAP). The weapon can be used to disable enemy fighters sensor (radar and EO), navigation avionics, flight controls, or computers, or directly against an incoming missile itself. The SPM should be able to guide itself to close proximity of its aircraft or missile target so that a simple fuze can trigger a small, omni-directional ECM warhead or directional HE/fragmentation warhead within the appropriate lethal radius of the target.

A key advantage of this SPM is the potential of disabling an incoming interceptor missile without the need to hit or even come very close to the very small, high speed missile target. As

such, it may provide an effective self-protect system at a time when guided missiles (e.g., utilizing Infrared Focal Plane Array (IR FPA) seekers) are becoming almost impervious to conventional countermeasures.

This system is dependent on the availability (as is being projected) of aircraft avionics to detect and pinpoint missile launches to an accuracy of approximately one degree and accurately track them after launch.

The Electronic Countermeasure (ECM) concept warhead is described in detail in the classified New World Vistas report. (See the section on Munitions Panel.)

The alternative vehicle configuration is a more conventional forward launched missile with customized propulsion and control. A low level boost separates the missile from the aircraft before reaction controls provide a rapid turn to the desired heading while the missile is at low speed. Optimized propulsion burns and control are necessary to achieve lethal miss distance at very short range.

Key Enabling Technologies

The advent of this new class of 360° self-protect missile capable of intercepting incoming threat missiles depends on:

- Maturing miniature reaction propulsion devices with a high degree of control.
- Electronic Countermeasure Warhead
- A small (10 pound class) directional HE/fragmentation warhead and fuse capable of missile kill at 10 to 20 feet.

Stop Invading Armies With Autonomous Miniature Munitions (AMM)

Introduction

A continuing top level military task will be to rapidly stop the forward movement of invading armies. The concept of Autonomous Miniature Munitions (AMM) adds significant capabilities for carrying out this requirement. AMM technology yields a small, highly effective unitary munition which will provide the Air Force with a force-multiplying capability for a wide range of air-to-surface warfighting tasks. The key element of the success of this concept is significantly increasing the tempo or "pace" of warefare. AMM alters the paradigm of cluster munition dispensing to one of munition commitment based on maximizing kills per sortie. The enhanced lethality of AMM allows the utilization of these systems as autonomous multi-mission munitions. The reduction in mission payload requirements can be leveraged against the aircraft platform design to yield improved tradeoffs between mission payload, aircraft range, stealth, and cost.

Concept

AMMs are small (<100 pound), highly lethal ($P_{SK} \approx 0.8$) munitions capable of autonomous target acquisition and classification of targets. AMMs will integrate "adaptable warheads" which will give them capabilities against a wide range of target types. A single warhead package can

be effectively employed against the full range of material targets from light trucks, relocatable targets, and Surface to Air Missile (SAM) installations to heavy armor. AMMs will reduce the payload weight carried on aircraft for classical air power missions such as interdiction, close air support, and Suppression of Enemy Air Defense (SEAD). Near term (< 5 years) implementation using modified dispensing techniques on current aircraft will provide a significant reduction in the number of sorties required to eliminate the enemy's warfighting capability. Long term impact (10 years +) will allow future aircraft to be smaller, lighter, and less expensive. The small size of the individual munitions is consistent with internal carriage and dispensing associated with low visibility aircraft. The broad range of targets addressed by the munition will be compatible with the evolution to dynamic battlefield management in that sortie allocation to selected targets can be tasked in broader categories with the ability to change target objectives at the last minute.

Enabling Technologies

The current joint service Low Cost Anti-Armor System (LOCAAS) program is a critical experiment with the objective of demonstrating the integration of several key technologies associated with AMM in a realistic prototype configuration. The integration technologies include:

- Autonomous target detection and classification based on solid state, laser radar (LADAR)
- Adaptive lethality
- Compact maneuvering airframes

Longer term vision of the enabling technologies include: High Energy Density Materials (HEDM); tunable energy release from both explosives and propellants; precision low-energy initiation systems such as direct optical initiation; high resolution solid-state laser radar seekers; a "two order of magnitude" increase in analog to digital (A-D) converter speed; an efficient and affordable reaction control system; and a multi-burn controllable solid propellant or small, inexpensive turbine engines.

Enabling Technologies and Capabilities

As we developed our capability needs and concepts, certain key "enabling technologies and capabilities" emerged that have such a wide range of applications that the Munitions Panel felt these should be highlighted. In identifying these critical technologies the Munitions Panel established the following selection criteria: (1) the technology should be critical to a broad range of weapon systems, (2) the commercial sector will develop the technology, but not at the required pace or with the specific characteristics required or, (3) the technology has a unique Department of Defense application. These critical technologies and capabilities are tabulated below:

Technologies:

- Micro-navigation sensor technology
- Electronic countermeasure weapon technologies
- Propulsion energy management

Capabilities:

- Hypervelocity weapons technology
- Autonomous target acquisition/classification
- Counter-countermeasures
- Battle damage assessment
- Identification Friend or Foe (IFF)

Another critical technology for future munitions (but which does not strictly meet the third of our "criterion" above) is in the area of high speed digital and analog-to-digital signal processing. However, it is anticipated that continued advances in commercial components will satisfy this need for munitions applications.

Recommendations

Identifying the Air Force s severest challenges to successful mission completion over the next several decades is both an exciting and an imprecise endeavor. However, we believe we have focused on those areas where improvements to weaponry can make substantial contributions to deter and/or prevail in future conflicts. Some of the technologies are here, others are just around the corner, and certain key ones await fundamental breakthroughs in materials or processes. But combined with creative approaches to weaponry design, all offer crucial enhancements to the Air Force warfighting capabilities. The following recommendations will effectively exploit and implement the high pay-off munitions concepts identified to address projected U.S. defense needs.

Airborne Ballistic Interceptor

Conduct a detailed concept definition study focused on the ABI concept and technology descriptions in this report. Move ahead into system development.

Aircraft Self Protection Missile

Conduct a concept definition study that evaluates and selects between the concepts proposed here—the reaction controlled projectile and a small, agile missile. A technology demonstration is needed for the "reaction controlled projectile".

ECM Cruise Missile

Sponsor a multi-year technology demonstration of an ECM warhead that could be carried on a cruise missile and accomplish the tasks described in this report.

Miniature Autonomous Munitions

Put together a miniature autonomous weapons program that will provide some near-term options and develop the technology base for the future.

- Emphasize kills per sortie on all munitions to increase the pace of warfare.

- Conduct a technology demonstration of the LOCAAS Munition showing autonomous battlefield target detection, acquisition, and destruction of mobile targets.
- Pursue sensor and signal processing technology to improve target acquisition and classification; establish specific milestones and address the expanded target spectrum.
- Demonstrate the capability to autonomously attack fixed targets.
- Set up a five-year program culminating in a technology demonstration of powered flight for extended range of these miniature autonomous systems.

Hard Target Penetrators

Conduct research to demonstrate a small (approximately 20 kg high explosive warhead) high velocity penetrator. The research plan must have specific milestones. The concept for delivery could be built around the hypervelocity missile developed for the ABI.

Enabling Technologies

Create specific plans with milestones for the following evolving technologies:

- High energy explosives, i.e., a 60% increase in delivered energy;
- High specific energy controllable propellant, i.e., 15% increase;
- Electronic Countermeasure warhead technologies;
- Plan for scramjet engine development.

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1.0 Introduction

The Munitions Panel has identified several high payoff munition concepts that address recognized, future U.S. defense needs. The concepts are achievable within the next 10-30 years and will significantly enhance the warfighting capabilities of the U.S. Air Force. We have divided our prioritized list of nine Capability Needs and Weapons Concepts so as to address them in two groups. The first group lists four needs and concepts which are discussed in some detail. The second list of five additional Capability Needs and Weapon Concepts are discussed in summary form. In general, we focused on smaller, lighter, agile, more lethal, and more affordable weapons that can enhance Air Force munitions and the target strike capability of the delivery platform.

During the next two decades, many countries will acquire very high technology systems such as ballistic missiles, highly effective air-to-air missiles, armies equipped with modern systems, and integrated information/sensor systems. An assessment of the most critical needs and most highly leveraged solutions has led to the identification of potential system concepts described in the report.

We arrived at our assessment of pressing capability needs by reviewing the current and future international geopolitical and economic climate as it relates to national defense. We then interpreted this environment in terms of generalized future military issues. We subsequently identified pervasive, tough problems of great interest to the U.S. Air Force. We followed this by identifying conventional wisdom, potential paradigm shifts, and capability needs that support new weapon concepts.

1.1 The Political And Economic Environment

The political and economic environment sets the context in which national security decisions are made. The context for the early decades of the twenty first century is significantly different than for the decades of the Cold War. The stresses and conflicts of the first five years of the post-Cold War era are important indicators of a period of instability. However, many of the characteristics of the next decade have been shaped by major past events such as the Viet Nam War and the emergence of Japan and Germany as economic powers.

Our Panel's desire was to identify or project those aspects of the political and economic context that have a significant impact on decisions about defense technology—specifically weapons technology.

The shift from a bi-polar to a multi-polar world signals the end of the superpowers nuclear standoff and the start of an era where nuclear deterrence is less influential, and concern about the proliferation of weapons of mass destruction leads to the support of significant investment in counterproliferation efforts. The end of the two-superpower nuclear era and the collapse of the Soviet Union have also made the world "safe for conventional war" and there has been a substantial rise in religious or factional war and terrorism. These kinds of conflicts often involve civil populations and are very complex as illustrated by the war in Bosnia. How things will look in the modern news media (i.e. television news coverage such as CNN) adds a new dimension to military planning.

Perhaps the most challenging problem of all is the rapid advance of commercial technology in areas of importance to military operations, such as electronics, and the spread of modern

commercial and military technology around the world. Our military operational and technical planning must include the increasing technical capability among potential adversaries.

Finally, the end of the Cold War, the international trade balance, the federal budget deficit, and a strong anti-tax movement combine to create a decreasing defense budget environment that is likely to last for many years. This presents a major challenge for military planners and for the technology community to create technologies that retain the military advantage at increasingly reduced costs.

1.2 Munitions Panel Methodology/Approach

The Munitions Panel objective was to determine the high payoff munition concepts achievable within the next 10-30 years. These concepts will significantly enhance the warfighting capabilities of the Air Force, emphasizing smaller, lighter and more affordable weapons that do not compromise the target strike capability of the delivery platform and mitigate collateral damage.

The Munitions Panel's approach to identifying *New World Vista* concepts that are candidates for exploitation in the near term and the far term consisted of establishing the current political and economic climate noted in section 1.1. This was followed by interpreting the environment in generalized terms to describe what is termed the "Military Environment."

The "Military Environment" will consist of:

- Coalition wars
- Joint service acquisitions
- Emphasis on cost/affordability
- Decline of forward basing
- Proliferation of Weapons of Mass Destruction (WMD)
- Increasing reliance on space for communication and intelligence
- Pervasive use of Global Positioning Satellite (GPS) system
- Low observable technology (stealth)
- Precision guided munitions
- Reliance on large aircraft for battle management and reconnaissance
- Establishment and maintenance of air superiority
- Reduced force structure
- Low intensity conflict

At this point, militarily pervasive or tough problems and threats as they relate to the Air Force from a munitions point of view were identified. The following list, although not all inclusive, captures the areas of primary concern:

- Theater/national defense (Theater, Intercontinental Ballistic Missiles)
- Aircraft self-defense/regain air-to-air combat edge

- Electronic warfare/prevent adversary's electronic operations
- Stop invading armies/autonomous miniature munitions
- Low observable cruise missile defense
- Hardened, deeply buried command and control (C^2) sites, and buried munition storage and manufacturing facilities located in caves and bunkers
- Relocatable targets
- Rapid response - 5 minute attack (100km)
- Nuclear, Biological, and Chemical (NBC) targets (manufacturing/storage facilities)
- Identification Friend or Foe (IFF)
- Counter and counter-countermeasures
- Information warfare
- Camouflage, concealment, and deception
- Minimal collateral damage
- Control of space
- Active defensive systems
- Survivability
- Terrorist actions
- Technology leveling (i.e. dispersion of high technology worldwide)

The next step in the process of identifying the munition concepts consisted of an assessment of other issues that could impact future development of weapons. The following list typifies items that fall into this category:

- Reliance on commercial/civilian technology
- Just in time production
- Flexible manufacturing
- Internal munitions carriage
- Affordable miniaturized precision guided munitions
- Minimal friendly casualties
- Autonomous weapons
- All weather
- Multiple kills per pass
- Single shot/single kill

- Simplified training
- Extensive simulation and modeling
- Stealthy smart sensors
- Low observable external carriage stores
- Integrated weapon systems
- Application specific weapons
- Precision real-time targeting
- Cooperative engagements
- Non-lethal kill (immobilization of personnel and vehicles)
- Open architecture systems

In view of all these considerations, the Panel compiled a list of enabling technologies/ capabilities:

- "Adaptive lethality"
- Direct optical initiation of warheads
- Photonic materials
- Subminiature electronics
- Ultra-high speed data transmission
- High temperature, high strength materials
- Lightweight, high strength composite materials
- Conducting polymers
- Ultracapacitor-based power supplies
- High energy density materials - propellants and explosives
- High power, low cost solid state lasers
- Small, high power microwave sources
- Signature management
- Image/data compression
- Sensor fusion
- Massively parallel processors
- Passive millimeter wave focal plane arrays
- Ultra-wideband ground/foliage penetrating radar
- Optical signal processing

- Artificial retinas
- Hypersonic propulsion
- Neural and genetic algorithms for target acquisition
- Real-time modeling and simulation
- Smart fuze
- Agile/flexible control surfaces using smart materials
- Automated mission planning and decision making
- Signatureless propulsion
- Efficient lethal mechanism energy coupling
- Miniaturized electro-optical mechanical systems

Having rather loosely established some bounds to the problem, numerous munition concepts were postulated that addressed the militarily pervasive or tough problems. Several of them are significantly intriguing and are presented because of their potential impact on future conflicts.

2.0 Munition Concepts

2.1 Airborne Interceptor (ABI)

Introduction

The mobility of the airplane and UAVs can be exploited by the USAF in ballistic missile defense, provided the aircraft carries an interceptor missile with the necessary capability for ballistic target destruction before the target has reached apogee or has dispensed its submunitions. The key requirements are target detection, acquisition, interceptor high speed flight, aimpoint selection, intercept guidance, and target kill. The ABI can be launched from either fighters, bombers or UAVs. A high velocity Airborne Interceptor (ABI) missile system can be built today that could effectively intercept theater ballistic missiles during their boost/ascent phase. The SAB has shown that full 360° azimuthal coverage from a single aircraft is easily obtained, thus reducing by a factor of two the required number of aircraft on patrol from the number used in previous COEAs. This could be especially important for UCAV's or UAV's where wingmen are not required. The acquisition system can be installed in a pod which provides flexibility to the wing commander for aircraft assignment. This missile could also provide the basis for other high velocity weapons that would dramatically increase the attack reach from an airplane. It also has the potential to be expanded into a national missile defense capability. An ABI could be developed in partnership with both the U.S. Navy and NATO allies in a joint program.

Concept

Our recommended approach is an ABI missile which is launched from a fighter, bomber, or an uninhabited aircraft with a stand-off range of 1200km against Theater Ballistic Missiles (TBM) with unitary warheads and other time critical ballistic missiles. TMB's with submunitions could be destroyed, prior to submunitions dispension, from a stand-off range of 300 to 450km, which is comparable to the ABL. This kinetic energy missile will have a velocity of about 5km/second and have a hit to kill probability of about 80%. It is important to recognize that the TBM warhead is physically destroyed at intercept, thus terminating the TBM mission at that instant. Shortfall of an intact nuclear, biological or chemical warhead no longer is an issue as it is with the ABL. All of the technology to deliver this missile system exists today. It would be a significant complimentary technology to the ABL for direct destruction of ballistic missile warheads before they fractionate into separate subminitions. The ABI represents the current lowest technical risk and can be fielded in ten years or less. Launch platforms to deliver the ABI exist in the current force structure. In addtion, UAVs such as the Tier II Plus and Tier III Minus ACTD programs with their long loiter time at high altitude are extremely attractive as ABI launch aircraft. The ABI's key advantages are: a 2:1 velocity advantage over the threat missile; physical destruction of the threat missile warhead; and an all-weather capability. The potential is large for such a system to significantly enhance the U.S. Air Force posture for putting a lid on rogue nations.

Again, an ABI is launched from a fighter, bomber or uninhabited aircraft at a stand-off range of 1200km against TBMs with unitary warheads. That is, unitary warheads can be destroyed at any point along the TBM trajectory. When clouds exist along the line of sight, the resulting delay only becomes important to TBM s with fractionated warheads. The effect of clouds could reduce the stand-off range for submunitioned TBMs from 450km to 300km. All-weather

off-board sensors (from surface or air, or space sensors) could regain this 150km by providing TBM launch and location to the ABI launch aircraft (see figure 1).

The technology for such an ABI exists today. Robust on-board target acquisition is already available from an Infrared Search and Track/Laser Radar (IRST/LADAR) when the target climbs above the clouds. Acquisition ranges over 600km are available. (See figures 2 and 3.)

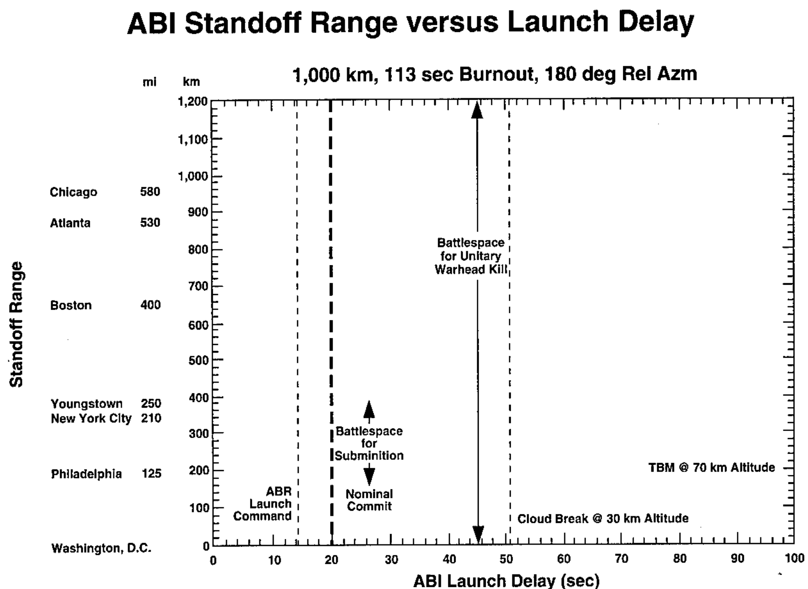


Figure 1

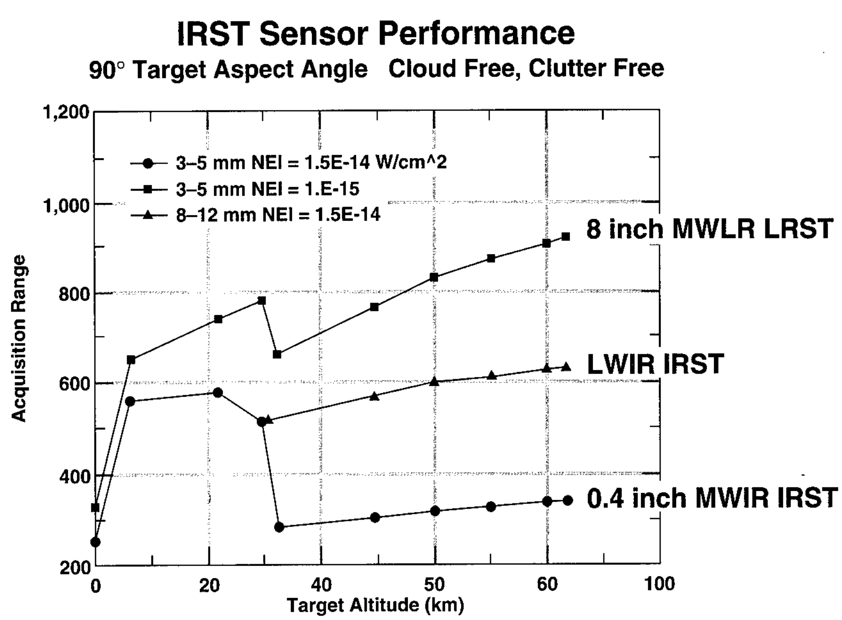


Figure 2

IRST/LADAR Conclusions

		Percent Cloud Free Above Given Altitude				
	Altitude km	Korea %	Iraq %	Iran %	Time After TBM Launch (sec)	
					<600 km	<1,000 km
Summer	4	40–50	>90	80–90	25	35
	6	50–60	>90	>90	30	42
	8	60–70	>90	>90	35	47
	10	70–80	>90	>90	37	50
Spring	6	60	60	60	30	42
Fall	6	70	80	90	30	42
Winter	6	80–90	60–70	80	30	42
	10	>90	>90	>90	37	50
Stand Off Range Improvement of 5 km for Each Second Launch Delay is Shortened						

- **Probablity >90% Cloud Free for TBM Above 10 km Except for Korea Where It is 70% to 80% in Summer**

On Board IRST/LADAR Will Provide Significant Military Value to Aircraft Autonomous Performance

Figure 3

Intercept guidance technology exists and has been demonstrated in high closing velocity demos such as: the successful intercept of an ICBM in the Homing Overlay Experiment at 10km/second; the HEDI for sensor window cooling and tracking accuracy; and the ERINT for PAC-III and Stinger for operational hit-to-kill homing. These systems have reaction times of 10 to 80ms, which are consistent with their respective closing speeds to obtain hit distributions within a 25cm radius circle of the preferred lethal hit point. This accuracy (with lethality enhancement, if needed) will physically destroy all warheads in the **ascent** phase, thus defeating these ballistic missile's mission. Short fall is therefore not an issue.

Needs

At this time, the technology does not exist to reliably kill all types of TBM warheads during the **descent** phase, particularly chemical and biological submunitions and their dispensed agents. A more robust solution would be to attack these weapons during the **ascent** phase when they are most vulnerable, preferably before they dispense submunitions or while the submunitions are still clustered close together so that a lethality enhancement that extends from the Kinetic Kill Vehicle (KKV) in the last few seconds before intercept would physically destroy all containers of chemical or biological agents.

- The system would be air launched for fast response to any part of the world. Aircraft can safely operate outside the borders of potential enemies with the ability to reach into the launch areas with a long range, high velocity missile and destroy the threat missile while it is still in its ascent phase, before it has dispensed the submunitions.
- This system should be effective against nuclear, HE, chemical and biological payloads.
- The system should be able to destroy unitary warheads at any portion in the ballistic missile trajectory.
- The system should be able to destroy submunition warheads during the ascent phase.

Supporting technologies required and current status: the critical element needed to provide the necessary velocity is a solid rocket system that is the correct size. Available off-the-shelf rockets are not in the size range to provide attractive operational characteristics. No new rocket technology is needed—we need to just build the correct delta-V to exploit the Ballistic Missile Defense Office (BMDO) KKV hardware.

- Hypersonic velocity for significant range for the available engagement times exists today.
- Existing solid rocket propulsion technology should be sized correctly for the mission.
- Hit-to-kill technology with kinetic energy for target destruction has been developed by BMDO and is ready for application. In fact, the ABI requirements for TBMs are less stressing than those of the current Atmospheric Interceptor Technology (AIT) programs.
- System time constant requirement for hit-to-kill has been operationally demonstrated at 1km/second closing velocities for Redeye and Stinger. The corresponding system time constant required is about 80ms. Battle effectiveness in Afghanistan was demonstrated, since over 80% of the Stingers fired destroyed an aircraft target with a single Stinger.

The extension to 5km/second closing velocity for TBM interception by ABIs drives the acceptable KKV time constant to about 15 to 20ms (or five times faster than Stinger). The KKVs in the AIT program are designed for ICBM closing velocities of 10km/second. Their time constants are in the 15ms or less range and should be more than adequate for ABIs against TBMs.

Four different flight demonstrations are available to confirm that these capabilities are available now.

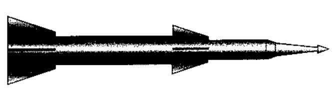
- The Homing Overlay Experiments (HOE) conducted in the early 1980's successfully hit and destroyed an incoming ICBM Reentry Vehicle (RV) over Kwajelein Island after it was launched from Vandenberg AFB. This is the proof of concept testing for accuracy at 10km/second closing velocity which is the upper end of the closing velocity requirements.

- The ERINT missile selected for the upgraded Patriot system (PAC-III) has special side thrust rockets far forward of its c.g. to provide the fast generation of angle of attack for successful aerodynamic maneuverability against TBMs in their terminal phase. Three successful flight tests of the PAC-III have demonstrated hit-to-kill technology.
- Successful sensor window cooling has been demonstrated on the HEDI program for dynamic pressure of two and four times greater than a TBM ABI could experience.
- Demonstration of system integration would best be done using the proper rocket motors after detailed concept definition studies.

The ABI missile exploits the component miniaturization research of SDIO/BMDO over the last twelve years. The resulting missile has a high fraction of total weight allocated to the solid rocket propulsion, providing KKV velocities of about 4.5 to 5km/second, which is twice that of the TBM targets. A potential missile design concept and key characteristics are provided in figure 4. The robustness of the ABI is apparent because the typical engagement kinematics indicated a 2:1 ABI speed advantage. This allows:

- Significant relaxation of the acceptable launch delay time, including delay until the TBM clears the clouds.
- Intercept of crossing (or even outgoing) targets for excellent reach into hostile countries.

2002 Epoch Strawman ABI missile design



Design description	Nominal booster performance
• Weights (kg): — Total missile 623.1 – AIT KKV and shroud 25 – First stage with interstage 442.9 – Second stage with interstage 155.2 • Missile dimensions: — Length = 427 cm (≈14 ft) — Max. body diameter = 45 cm (≈1.5 ft) • KKV specifications: — Length with shroud 135 cm — Length without shroud 93 cm — Propulsive divert 600 m/sec — Divert acceleration 15 g's	• First stage performance — Stored Delta-V (Ideal Vbo) = 2.4 km/sec — Burn time = 6 sec — Total impulse = 983 kN-sec — Specific impulse = 270 sec — Two segment motor • Second stage performance — Stored Delta-V (Ideal Vbo) = 3.1 km/sec — Burn time = 9 sec — Total impulse = 337 kN-sec — Specific impulse = 283 sec • Total booster performance — Stored Delta-V (Ideal Vbo) = 5.5 km/sec — Burn time = 15 sec

Figure 4

- Intercept of the TBM in the first third of its flight path (well before apogee) for physical destruction of all classes of warheads (nuclear, biological, chemical and high explosive) generally over enemy territory. Short fall of the warhead is no longer an issue. Aim point selection is also simplified because there is a well defined target trajectory and no missile breakup during the ascent phase.
- Defended area coverage is orders of magnitude larger than other systems intercepting the TBM in its terminal or upper tier stage of flight. This is shown in figure 5.

ABI System Provides Broad Theater Coverage

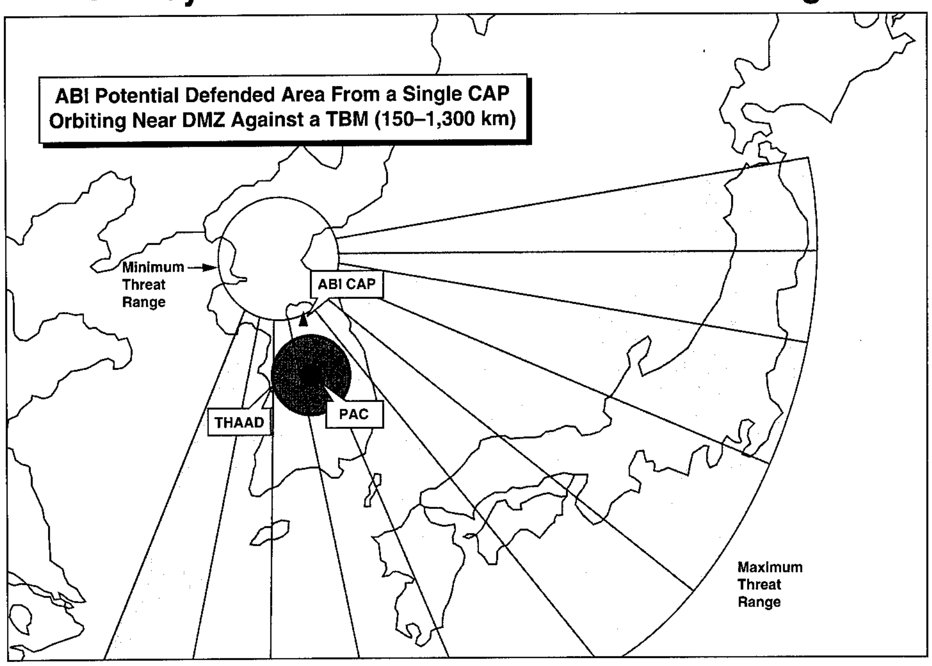


Figure 5

Full 360° coverage is available from a single aircraft, thus reducing the required aircraft Combat Air Patrol (CAP) by a factor of two.

Figure 1 also demonstrates that the ABI and its launching aircraft are always above the clouds, even for an offboard radar target designation that allows launch of the ABI when the TBM is still in the clouds. The use of Electro Optics for detection, tracking and communication is highly desired because of their fast action, precision tracking, and good countermeasures capability contained in small, lightweight units that easily fit in operational aircraft. Thus, the baseline system should be autonomous, onboard the launching aircraft, integrated with the launching aircraft's radar, and also able to accept target designations from offboard sources when they are available.

The long range acquisition capability of an IRST sensor at 11km altitude is shown in figure 2 for collecting optics of either 0.4 or 8 inches with cloud free line-of-sight and no ground clutter. Curvature of the earth and atmospheric attenuation are included and their effects can be seen by the increasing acquisition range as the TBM gains altitude. Booster Engine Cutoff (BECO) occurs around 30km altitude but the hot body is still easily tracked after BECO. We conclude that a larger range of key parameters exists for detailed design of the EO acquisition and tracking system. The ballistic missile is a very strong IR source and we should exploit that characteristic. The robust kinematics of the ABI are shown in figure 1 as stand-off range for a wide range of launch delays.

The ABI could be used by the U.S. Navy (USN) as well as USAF aircraft. The USN may choose to use only the second stage plus KKV to allow greater penetration into the rogue country. Recovery of the loaded Aircraft aboard an aircraft carrier may limit the total weight allowed. The Navy could also use this KKV as an Aegis ship launched system.

Recommendation

The USAF should conduct detailed concept definition studies rather than the highly constrained studies of the past.

The USAF should build and flight test the ABI rocket motors because they provide a quantum improvement in air launched weapons and are applicable to most SEAD, air defense and strike missions. This propulsion system is available today and allows the USAF to exploit the time responsiveness of manned aircraft or uninhabited combat aircraft by providing a significant increase in power projection and reach into hostile territory.

2.2 Prevent Enemy Electronic Operations

Introduction

Conducting military operations is increasingly dependent on electronic systems. Information collectors, processors, distributors, sensors, weapons, and Command, Control, Communications, Computers, and Information (C^4I) systems comprise a large set of very high value targets that are vulnerable to damage by electronic countermeasures (ECM). Over the past decade, ECM technologies have been sufficiently developed (in both the U.S. and abroad) to consider practical development of weapons that employ these technologies. While such systems could be utilized from an aircraft directly, the use of a missile lowers the requirements and risks because considerably lower levels of power can be effective at shorter ranges to the target and it also reduces fratricide concerns. A specific Electronic Countermeasure concept is described in detail in the classified New World Vistas report. (See the section on Munitions Panel.) The concept is illustrated generically in figure 6.

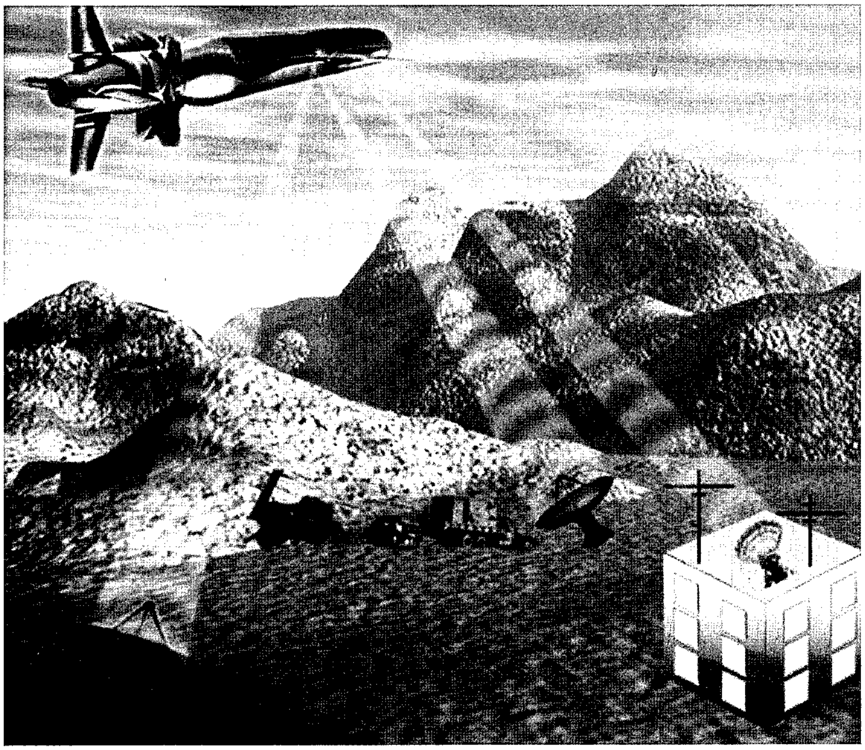


Figure 6 Cruise Missile to Incapacitate Enemy Electronics

2.3 Self Protection Missiles

Introduction

In May 1995, rebel ground forces in Bosnia shot down an F-16 using a portable surface-to-air missile. In upcoming regional conflicts, one of our AWACS or JSTARS aircraft could very conceivably be targeted by a medium or long-range, air-to-air, or surface-to-air missile. Even our air superiority fighters, as well as our air mobility transport aircraft are at great risk due to proliferating dogfight missiles.

There are a number of systems and tactics currently employed by our aircraft to survive in-air combat. First, there is the high-G escape maneuver employed in Viet Nam to escape the incoming interceptor missile at the last moment. The maneuver tactic is of marginal value with today's better guided and more maneuverable missiles. It is expected to be useless in the near future.

A second option is to develop and employ longer-range missiles to "outreach" the threat aircraft. Advanced Medium Range Air-to-Air Missile (AMRAAM) gives us a temporary advantage in the medium range regime (3-10NM), but that can be lost as enemy missiles increase in range unless we improve propulsion in AMRAAM and our weapon control sensors on aircraft.

In the dogfight arena, our current AIM-9s are at a disadvantage versus the Python and the AA-11. Unfortunately, future dogfights are likely to be lethal to both parties since short range missiles are launch and leave.

The third option is to employ countermeasures against ground, sea, or air weapon controllers, against adversary aircraft and/or against the threat missile itself. However, today s state-of-the-art countermeasures (chaff and flares) may be of mixed value. For example, Infrared Focal Plane Arrays (IRFPA) have proven to be very difficult to deceive with flares, and better systems are on their way. Nevertheless, they will remain an important part of our survival package. ECM systems offer a new option. See the Directed Energy Panel s report for an assessment of their employment as a self-protection device on aircraft.

Concept: New Self-Protection Missile

A number of currently emerging technologies can be combined to make a totally new and innovative Self-Protection Missile (SPM) practical. (See figure 7.) The airframe is based on the kill vehicle designs being developed by BMDO. These vehicles employ reaction thrusters to

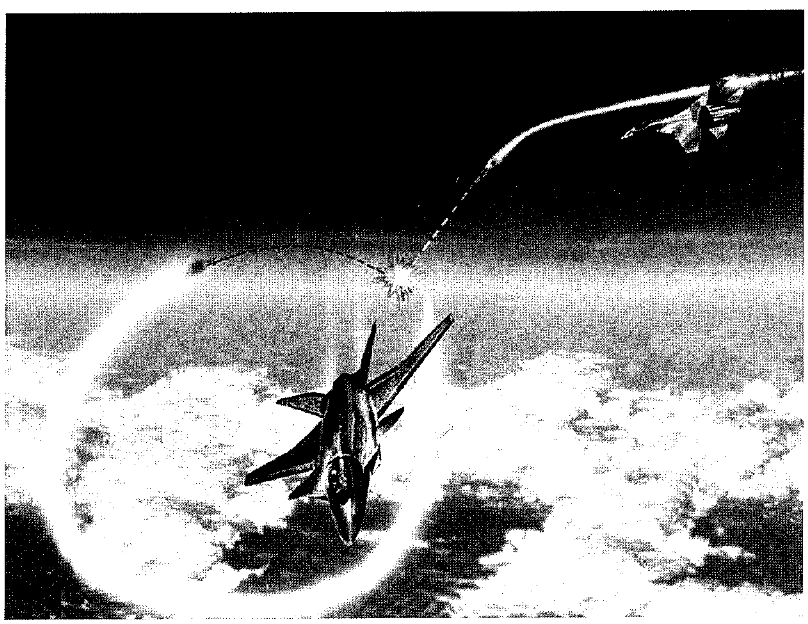


Figure 7 Self Protect Missile

suspend, stabilize, and maneuver. Since they can operate at low or zero velocity, they can separate from the launch aircraft in any direction, making 360° defense feasible. Several such vehicles have been hover-tested at Edwards AFB; and several have been launched at White Sands Missile Range with partial success. Problems with target deployment and first stage boosters have limited test completion, but the kill vehicles have operated (suspended, stabilized, and diverted while tracking the target) successfully.

An alternate, more conventional, vehicle would offer lower risk, but would require longer keepout range. The missile would be forward launched with a low level thruster. Reaction control could be employed at the low velocity and a snap-turn accomplished to the desired heading. Then an appropriate thrust is provided to achieve ideal intercept kinematics.

Currently, terminal guidance could be millimeter-wave radar or infrared imaging. Perhaps later inertial guidance could be used if warhead lethality breakthroughs occur, which seems possible. Note that guidance and control of the SPM is simplified by the nature of the encounter with the attacking missile. The attacking missile is locked on our aircraft so, at least in the initial stages, its radar cross-section should be very large. Furthermore, the attacking missile is attempting to fly a collision course with our aircraft; that is, a zero line-of-sight trajectory which simplifies the flight path of our SPM. In the limit, we could slide the SPM away from the aircraft along the line-of-sight and the threat missile would run into it. Because of this and the short flight duration, the possibility of a very simple, low cost inertial guidance package should be examined. Since some errors in fact do accrue, some form of guidance and an appropriate warhead would probably be required. Focused HE warheads with a problem solving fuze could provide the lethal radius necessary to kill a small incoming missile at 10 to 20 feet missile to missile distances.

There appears to be fairly substantial technical basis for making a SPM feasible and affordable. It should be small enough (100 to 200 pounds) to allow a reasonable load-out even on fighter size aircraft. It is important that the launch aircraft be provided detection and accurate direction of the incoming threat missile for the SPM to be successfully employed. An alternative Electronic Countermeasure (ECM) warhead concept is discussed in the NWV classified report (see Munitions Panel section).

2.4 Autonomous Miniature Munitions

Introduction

The munitions payload capability is in most cases a fixed percentage of a fighter aircrafts weight. The cost of a fighter aircraft is for the most part a direct function of its weight. If the weapons payload can be reduced to achieve equal or greater performance, the weight and hence the cost of the airplane may be significantly reduced. "Miniature munition" technology emphasizes the design of small, highly effective munitions which will provide the capability to perform a wide range of air warfare tasks with significantly reduced payload weights. The focus might be termed multi-mission munitions applicable to tasks such as interdiction and Suppression of Enemy Air Defenses (SEAD). The surface strike mission can be further subdivided into precision strike - point targets, and precision strike - area or anti-materiel targets. The primary focus here addresses unitions for use in the air-to-surface anti-materiel mission role. However, miniature munitions technology has a broader utility which will become apparent during the discussion of the concept to defeat the mobile target set.

Concept

The concept of an Autonomous Miniature Munition (AMM) alters the paradigm of cluster munition dispensing to one based on maximizing target kills per sortie. (See figure 8.) In the past, 1000-2000 pound class unitary and cluster weapons have been developed based on the carrying capacity of the aircraft weapons store stations. The premise here is that the lethality of

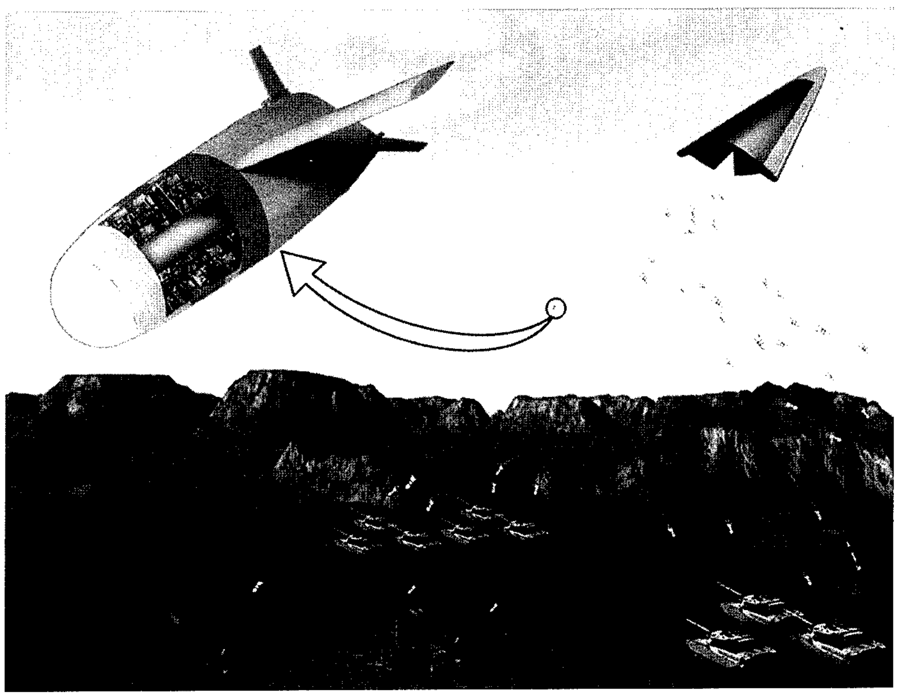


Figure 8 Autonomous Miniature Munition

the munition should be the determining factor in how one chooses to load out an aircraft to achieve maximum kills/sortie.

AMMs represent second generation smart munitions. First generation smart munitions are represented by current systems like the Sensor Fuzed Weapon (SFW), the Sense and Destroy Armor Munition (SADARM), and the Brilliant Antitank (BAT) munition. The common characteristic of these weapons is that they are cluster munitions capable of autonomous target detection. Their characterization as cluster munitions is associated with the limited size of the engagement footprint. In order to assure high kill probability, multiple munitions are dispensed to engage a single target or target array. The second generation autonomous munitions have much improved information fidelity through the use of advanced sensors such as laser radar (LADAR). When this improved fidelity is coupled with state-of-the-art processors and autonomous target acquisition/classification algorithms, two expanded capabilities result. First, the probability of false target detection is suppressed to such a low level as to permit a single munition to engage a footprint orders of magnitude larger than the first generation submunition. Secondly, targets can actually be classified by target type. Target type classification permits the use of advanced warhead design to maximize lethality against broad ranges of target types by modifying the kill mechanism in real time. When this complete suit of technologies is brought together at the munition design level the result is a small (50-100 pound) munition, not submunition, which has the lethality of current 500 pound and 1000 pound weapons against a broad range of targets. Their small size offers a force multiplier potential on current delivery platforms as well as the ability to limit collateral effects by killing the intended military target

with a lethal mechanism specifically suited to the target. The fact that they are capable of high performance against a broader range of target types, yields mission flexibility which supports dynamic battlefield management as opposed to munitions like the SFW which are anti-armor munitions and do not posses much soft kill potential against targets like SEAD.

Munitions which are designed for delivery from a dispenser, or cluster weapon, are called submunitions and to a large part have relied on the thought process that the more submunitions in a dispenser the better. Whereas, in fact, the design of the weapon should have started using the following basic relationship to maximize kills/sortie:

Kills/Sortie = $N\,P_{ssk} = N\,P_{e}\,P_{a/e}\,P_{h/a}\,P_{k/a}$ where:

P_{ssk}	=	probability of single shot kill
N	=	number of munitions
P_{e}	=	probability of engagement
$P_{a/e}$	=	probability of acquisition given an engagement
$P_{h/a}$	=	probability of hit given an acquisition
$P_{k/h}$	=	probability of kill given a hit.

When these individual characteristics are evaluated for emerging submunition technologies such as those represented by the joint service Low Cost Anti-Armor Submunition (LOCAAS), the single shot probability of kill at the submunition level is several orders of magnitude higher than any existing submunition currently utilized for surface strike applications. These developmental munitions are currently identified as submunitions primarily because of their small size (≈50-100 pound) in lieu of an assessment of the best way to exploit the technology on the battlefield. It is the realization that the combination of technologies available to today's munitions designers provides the capability to design highly lethal weapons in a much smaller package weight and volume than are currently characterized as unitary munitions. This forms the foundation of the AMM concept.

By reevaluating the employment strategy of submunition technology, the future payload weight required to accomplish a specific class of missions such as tactical interdiction or close air support can be significantly reduced and the versatility of the platform significantly increased. This reduction in payload requirements could be leveraged against delivery platform requirements to either reduce the total weapon system weight and cost or provide additional weight allowances for propulsion to address the requirements of the hypersonic fighter which would use speed as a defensive asset in combination with stealth.

Enabling Technologies

The enabling technologies in the AMM concept include:

- Autonomous target acquisition and classification
- Precision initiation system

- Adaptable warheads
- High energy density materials

Each of these is discussed in the following sections.

Autonomous Target Acquisition and Classification

The Autonomous Miniature Munition concept utilizes a unique seeker technology based on the development of a low cost, solid-state diode pumped laser seeker during the LOCAAS program. (See figure 9.) Captive and free flight testing of the LADAR seeker has demonstrated a 99% probability of acquiring mobile or relocatable targets with a 95% probability of classifying the targets in real-time. Currently, the algorithms utilize the range, and angle-angle data for

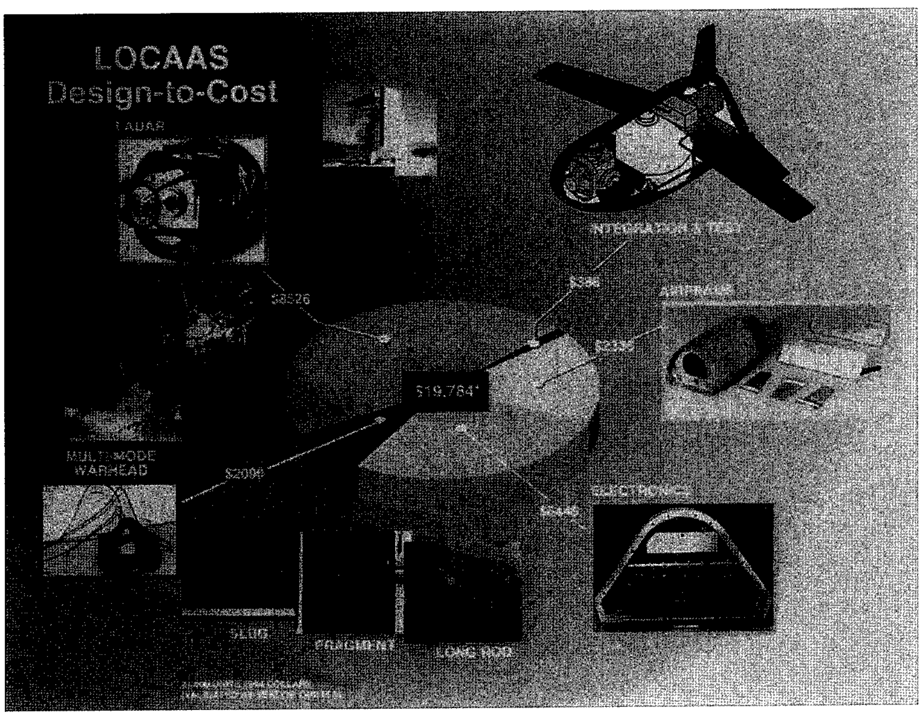


Figure 9 An Autonomous Miniature Munition Prototype: LOCAAS

target acquisition and classification. Intensity and reflectance information is also collected, but not used at this time. The LADAR seeker, because it is capable of collecting three dimensional data (6 inch resolution) about the target and background, requires less image processing than two dimensional systems such as imaging infrared seekers, and yields higher probabilities of target acquisition and classification. This can be partially attributed to the fact that the sensed 3-D imagery can be manipulated like CAD/CAM objects, thereby allowing simple, quick, geometric mensurations. Algorithms based on geometrical properties are inherently more robust and countermeasure resistant. Also, no extensive signature data base is required to define the

targets of interest, which eliminates mission planning requirements. Operating ranges for the LADAR seeker are nominally 2km, at an 18° depression angle, sweeping plus or minus 10° off the vehicle flight path. Future improvements are required to increase the range of the seeker by increasing the laser power output and the PRF. At a nominal velocity of 200kts and a 9:1 glide ratio, this equates to a search area 0.5 X 2 NM. Ranges in excess of 5km have been demonstrated to date. Similarly, the wavelength of the laser needs to be increased for the nominal .87 microns to something beyond 2.0 microns for eye safety reasons and better all-weather performance. Currently, weather utility is estimated to be > 94% worldwide using a nominal initial glide altitude of 500m. Tests have demonstrated the ability of the LADAR to see through four times the required rain rate, through most fog conditions, camouflage nets using last pulse logic, and most battlefield smoke obscurants.

The ability of the LADAR seeker to easily classify targets has prompted the development of adaptable warheads to better couple the warhead energy to the target to maximize the P_k. Futuristically, the LADAR seeker can be adapted to provide low cost terminal guidance for the Small Smart Hard Target Weapon (SSHTW) to eliminate Target Location Error (TLE) and provide an offset aimpoint capability. Conceptually, a powered version to provide stand-off and survivability for the launching platform needs to be considered. (See figure 10.)

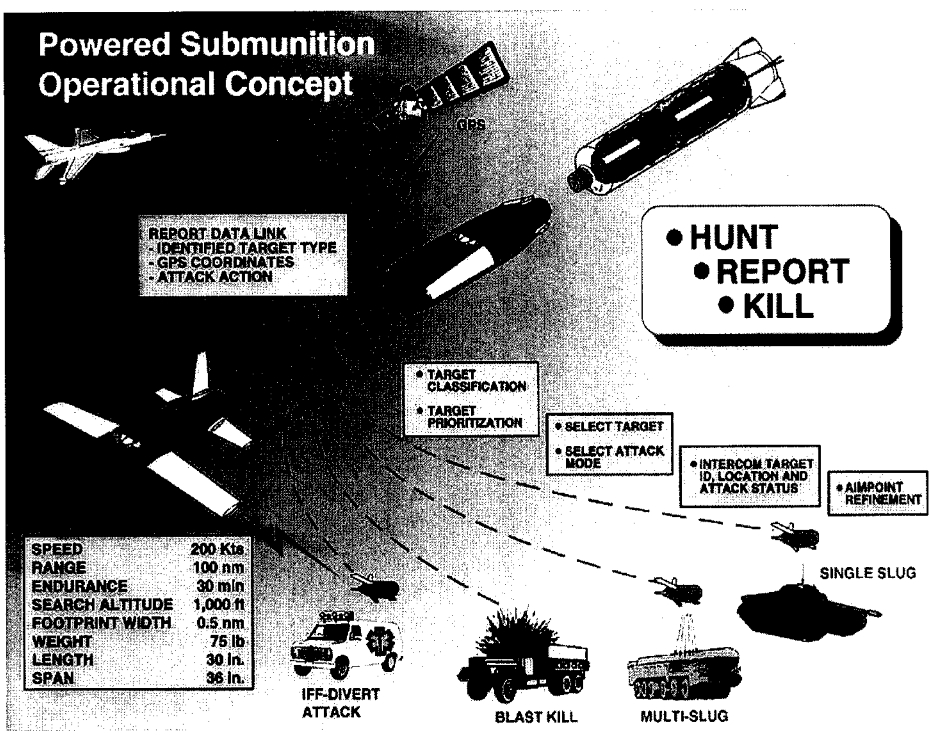


Figure 10 Powered Autonomous Miniature Munition for Increased Target Range/Capability

Precision Initiation Systems

Precision initiation systems such as Explosive Foil Initiation (EFI) have been an element of design in nuclear weapons for a long time. The use of this technology in conventional weapon systems was initially motivated by the improved reliability and safety offered by these systems. As their use became more common in the conventional weapon community, they have emerged as a fundamental element in innovative design solutions to today's and tomorrow's problem areas. This technology is evolving toward Direct Optical Initiation (DOI), significantly lower energy per initiation point requirements, and improved low cost manufacturing methods. The availability of future precision initiation systems will form the foundation of adaptive lethality in air warfare tasks beyond the surface strike area. Current technology supports anti-materiel warheads that can explosively form the liner materials into either an explosively formed projectile, a long stretchy rod, or a predetermined number of fragments. This is done real-time as a function of the laser seeker classification algorithm's determination of target type, i.e., a soft target like a SAM site or truck, or a hard target like a tank.

High Energy Density Materials

A major consideration in the development of miniature munitions is the lethality of small payloads. Enhanced lethality can result from: (a) an improved understanding of the process by which the target's operational effectiveness is disrupted; or (b) by improving the packaging and use of destructive power carried on the munition.

The near term (< 10 years) application of adaptable lethality based on target type identification falls into the first category. The long term (10-25 years) problem solutions will use approaches that exploit both the first and second categories.

Significant technology addressing the second category of approaches is associated with the energy packaging in conventional munitions. High Energy Density Materials (HEDM) are being manufactured based on a variety of new materials design approaches. One example is Metastable Interstitial Composite (MIC) materials. (See figure 11.) MIC materials are formulated

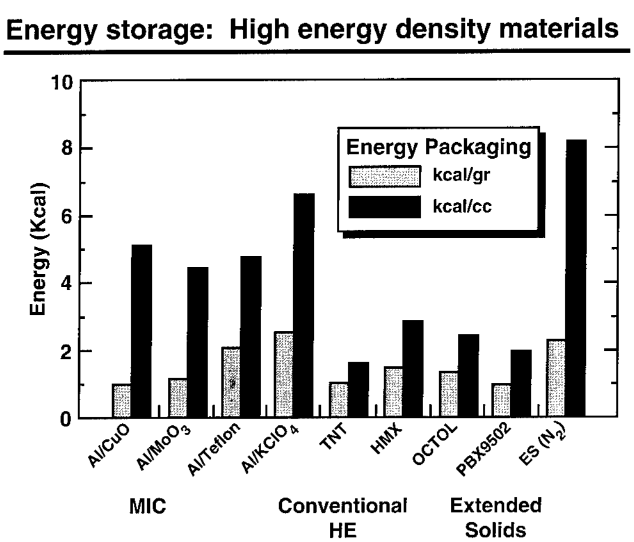


Figure 11

using two or more chemical species that are exothermically reactive with each other. Specific examples include Al/MoO_3, Al/Teflon, and $Al/KClO_4$. This means that the energy storage is intermolecular as opposed to intramolecular as it is in conventional explosives such as HMX and RDX. The key to the tunability of MIC materials is the ability to manufacture mixtures with controlled intimacy. A second technology base which addresses the fundamental energy packaging part of the weapon design problem is characterized as "extended solids." The design of an extended solid has a goal of 1 to 2 orders of magnitude gain in the energy available based on either weight or volume considerations. An interim goal is the development of extended solid Nitrogen, which is projected to have an energy of $33.6 KJ/cm^3$, versus $9.6 KJ/cm^3$ for HMX.

Adaptable Warheads

The weight of a warhead required to kill a target is determined by a number of system level parameters such as accuracy, aimpoint, and attack direction. However, the target design also has a large impact on size and type of warhead needed to obtain a specific level of lethality. The classic example of this is heavy armor which has driven missile designers to exploit shaped charge warheads for this task. Recent innovations in exploiting advanced initiation systems have demonstrated the ability to modify the explosive metal interaction based on target type information to generate kill mechanisms more appropriate to the target being attacked. The warhead lethal mechanism can then be modified in real time autonomously based on engagement information being gathered by high resolution seeker/sensor systems. This process occurs in the detonation time of the warhead ($\approx 100\ \mu s$) which provides the opportunity to address high speed closure.

2.5 Low Observable Cruise Missile Defense

Introduction

The Air Force Scientific Advisory Board 1993 Summer Study described a serious Low Observable Cruise Missile (LOCM) threat because of their proliferation and our lack of a robust solution. When countermeasures and other penaids are employed by the low observable cruise missile the problems become even more difficult.

After a modest assessment of alternative approaches it was concluded that kinematic kill (i.e. guided missiles) continue to provide the best solutions. However an adequate solution requires improvement of all elements of the intercept system: the off-board surveillance sensor; the interceptor aircraft sensors; and the interceptor missile guidance, control, propulsion and warhead/fuze.

Concept

AMRAAM is the all weather weapon currently available on our fighters to attack the cruise missile. As the cruise missile's cross section is reduced, the active radar seeker on the missile causes target acquisition at shorter and shorter ranges until it is too short for the missile to make end game corrections well enough to guide the lethal radius of the warhead. The designer's task is to first make the seeker regain target acquisition range larger than the minimum lock-on range. The minimum acceptable lock-on range depends on the time necessary to steer out the initial heading error and allow approximately 10 missile time constants of unsaturated

flight before reaching the point of closest approach. This is dependent on initial error, missile maneuverability, closing rate guidance law, and autopilot and warhead effective radius.

A very important tactic that must be employed with any existing or improved missile is to task the AWACS surveillance aircraft to place the interceptor aircraft at the ideal target aspect and heading. The ideal aspect provides the best combination of target cross section and closing rate as the missile time-to-go as seeker acquisition is maximized. The ideal heading results in the missile being on a collision course with the target at the end of boost.

Many techniques are employed in enhancing surveillance aircraft and interceptor aircraft systems to detect the cruise missile and to best position and prepare the missile. These are beyond the scope of the Munitions Panel. The balance of this paper addresses concepts and technologies for increasing target acquisition range and decreasing minimum acceptable lock-on range to intruder missiles.

Increasing Target Acquisition Range

The solution to this difficult problem starts with being positioned by the surveillance and control aircraft to be at the target aspect and heading presenting the best radar cross section. Antennas and transmitters must be improved to provide higher power-aperture products. Improvements in processing gain and sensitivity should be aggressively pursued. While the threat already embodies lower cross section, it is also expected that penaids and countermeasures and the presence of severe clutter will continue to aggravate the target acquisition problem. Hence the shifting to other radar frequencies (probably upward) as well as the use of semi-active midcourse (if the free control radar in the interceptor can increase the transmitted power) are potentially helpful options.

A complimentary electro-optical seeker (probably IRFPA) should be examined to enhance target acquisition as well as to improve guidance quality in the presence of jamming and clutter.

Reducing Minimum Lock-On Range

There are a number of techniques that can be aggregated to reduce minimum lock-on range, although none individually appear to offer dramatic improvements.

Since the missile flight path turning rate (g's) is g's = ng/v, we should address both the load factor and velocity. AMRAAM and most air-to-air missiles are designed to deliver a 30 g load factor only because it provides the canonical three times the target max g's and some margin. Greater load factors can be provided if the structural and equipment selections are properly made and the aerodynamic considerations are met. An even more effective choice might be to change the boost phase motor burn profile. If the boost velocity is kept low, the velocity at burnout could be half the current value; thus twice the turning rate can be achieved with the same load factor. Because of the low speed, reaction thrusters would be preferred to the use of aerodynamic surfaces.

Modern control theory employs a number of advance filter and algorithm concepts capable of reducing the time needed to achieve the desired collision course. They were not available or necessary at the time current missiles were in design, but today, they could add to control law and autopilot performance against this difficult target (LOCM).

As seeker acquisition range drops close to or even below the minimum desired guidance range, terminal miss increases. Under this circumstance, some kill capability can be regained if the warhead kill radius can be enlarged. Directional focused HEDM and ECM warheads are candidates to provide a greater kill radius.

Enabling Key Technologies

A number of technologies are supportive of the improvements desired above. There are four that are critical to achieving major improvements and enabling technological breakthroughs:

- Signal processing/algorithms and signal processors of sufficient speed.
- A two order of magnitude increase in Analog to Digital (A-D) converters.
- Efficient and affordable propulsion reaction control systems.
- Multi burn controllable solid propellant.

2.6 Buried Hard Targets Defeat

2.6.1 Small Smart Hard Target Weapon

Introduction

Historically, large accuracy errors in air dropped munitions have been compensated for by delivering multiple weapons and/or large weapons which maximize air blast and fragmentation (i.e., MK series bombs). Given the low probability of a direct hit on the target with unguided bombs, the large munition size was intended to provide a high probability of kill (P_k) given a near miss. In the case where penetrating weapons are required, accuracy becomes a more predominant factor than weapon yield.

Advanced guidance technology has greatly improved terminal accuracy. Laser radar (LADAR) guidance packages allow, affordable, precision guidance of the weapon, but not in all-weather conditions. All-weather terminal guidance using SAR technology is relatively mature, however, this is an expensive technology at this time. Next generation guidance concepts, such as Joint Direct Attack Munition (JDAM), will make unguided bombs obsolete, and provide adverse weather capability. Initial INS/GPS guidance kits will not possess the precision of the current laser kits, however, next generation systems will have a precision capability as GPS enhancements mature, or with the addition of terminal seekers. It is intuitive that as the weapon's accuracy improves, lower explosive yields could provide the same P_k as the larger weapons for certain targets.

Concepts

Development of smaller guided munitions would enhance flexibility in mission planning. Many more munitions could be carried for the same aircraft loadout thereby increasing the kills per sortie and the pace of warfare, or lighter loadouts could increase aircraft maneuverability and range, and still allow multiple target attack. Multiple stores carriage using multiple/triple ejector racks (MERS/TERS) or dispensers provide a force multiplier effect by allowing: multiple targets to be attacked on a single sortie; attack of multiple nodes on a single target for functional

kill; or allows attack of multiple bays of compartmented structures. These small weapons permit multiple carriage and targeting to ultimately increase sortie effectiveness, but at the same time minimize collateral damage. Intuitively, the logistical and life cycle cost advantages of smaller munitions are less, i.e., less airlift support and storage is required for the same number of munitions, leading to lower overall costs of the small weapon.

In addition to providing the stated advantages to currently employed aircraft, the Small Smart Hard Target Weapon (SSHTW) has the ability to impact future aircraft designs. Current aircraft are designed around the ability to deliver 2000 pound weapons. If a 250 pound weapon can be shown to be effective against a range of targets currently attacked by 2000 pound weapons, the size of future aircraft can be significantly reduced. This in turn has the ability to reduce the life cycle costs of these small aircraft—from design through production to daily operational requirements.

Additionally as targets may become harder, the same technology which could make smaller weapons effective could also be used to greatly increase the lethality of warheads in the 1000 to 2000 pound class.

Near Term Capability

The SSHTW in the near term would take advantage of conventional weapon technology advancements to prove the capabilities of a 250 pound class munition against soft to moderately hard fixed targets using miniaturized Differential GPS/INS guidance.

The Exploitation of Differential GPS for Guidance Enhancement (EDGE) High Gear Program is using a 15 inch diameter GBU-15 kit to demonstrate the accuracy of Differential GPS/INS guidance. Another method to improve GPS weapon accuracy is Wide Area GPS Enhancements (WAGE) which will be evaluated on the AGM-130, and in conjunction with a USAF evaluation of a weapon system called LongShot. The SSHTW concept would seek to miniaturize that guidance technology, associated flight control computer, electronic actuators, and thermal battery down to a 6 inch diameter. The warhead case would initially be fabricated from hardened steel and designed to penetrate over 6 feet of reinforced concrete, enough to be effective against a vast majority of targets. Once inside the target, the Hard Target Smart Fuze will be coupled with 50 pounds of high explosive for optimum detonation point and greatest weapon lethality. Additionally, the area of more energetic, insensitive, explosives will be maturing and increases in energy densities on the order of 150 to 300% can be expected in the next 10 years.

Long Term Capability

In the long term, the SSHTW performance would be enhanced to achieve the equivalent of 15 feet of reinforced concrete, and have less than a 3m CEP terminal accuracy. To achieve the goals, there are several technology challenges that must be overcome. Of paramount concern is miniaturization of the guidance and control section into a 6 inch diameter package. Additional challenges will be to control the impact conditions (impact velocity, angle of obliquity, and angle of attack) on a new weapon airframe to maximize penetration and, at the same time, prove the lethality of a radically smaller warhead carrying only one tenth the explosive weight of a BLU-109. Additionally, the weapon performance must not be degraded by ballistic

countermeasures such as burster-slabs, deflectors, boulder fields, or rock rubble. Fuzing for the weapon will require a predictive, look-ahead capability like a forward looking, ultra-wideband radar in addition to acceleration sensing devices. Ideally, a salvage mode would be incorporated in case of imminent case breakup. Terminal guidance using a low cost, solid state laser seeker will likely be an integral part of achieving high accuracy while mitigating countermeasures.

Conclusion

The Small Smart Hard Target Weapon is envisioned as a future munition that complements existing and currently planned conventional weapons. JDAM will be filling the void of adverse weather capable weapons as well as providing accurate conventional weapons for multiple carriage in bomber aircraft. JDAM PIP will increase the accuracy of the JDAM INS/GPS guidance by adding a terminal seeker. JDAM is seen as a near term capability (year 2000) that will fulfill many of the current warfighter deficiencies.

The SSHTW will fit into a far term capability (year 2005-2010) and provide a force multiplying capability for fighter aircraft and an ability to strike targets that would be overkill for a JDAM size weapon. LADAR sensing for precision accuracy and autonomous target acquisition, dense metal casing for improved penetration, autonomous fuzing for optimum detonation point within a target, cruise missile carriage for stand-off capabilities, and High Energy Density Material fills to improve explosive yields are all possible future considerations.

2.6.2 High Velocity Penetration Weapon (HIPEN)

Introduction

A key element of the Air Force's strike mission is the ability to destroy deeply buried targets. Current penetration weapons are large, low velocity systems requiring close proximity for weapon delivery. As can be seen from figure 12, penetration increases dramatically with velocity, up to the point where projectile deformation begins to limit performance. Low velocity penetrators depend on mass for penetration depth. Since penetration depth is also inversely proportional to the presented area of the weapon, very high length to diameter (l/d) ratios are required. Although penetration is aided by decreasing the presented area, the onset of project deformation occurs at much lower velocities. Figure 12 shows experimental data obtained for scaled penetrators. Based on this data it appears practical to expect a factor of four improvement in penetration depth with a two fold increase in impact velocity up to the velocity at which the penetrator begins to significantly deform. High strength materials and/or techniques to control penetrator nose deformation could potentially extend this limiting velocity even higher.

Concept

This concept builds on the SSHTW and the Airborne Interceptor discussed in sections 2.6.1 and 2.1 to provide a quick reaction, long range deep penetration weapon. The high performance propulsion system of the Airborne Interceptor, coupled with evolved, advanced guidance components suggested for the SSHTW, will provide a capability to strike targets hundreds of kilometers away, within minutes.

SAC-5 concrete penetration experiments compared with analytical theory

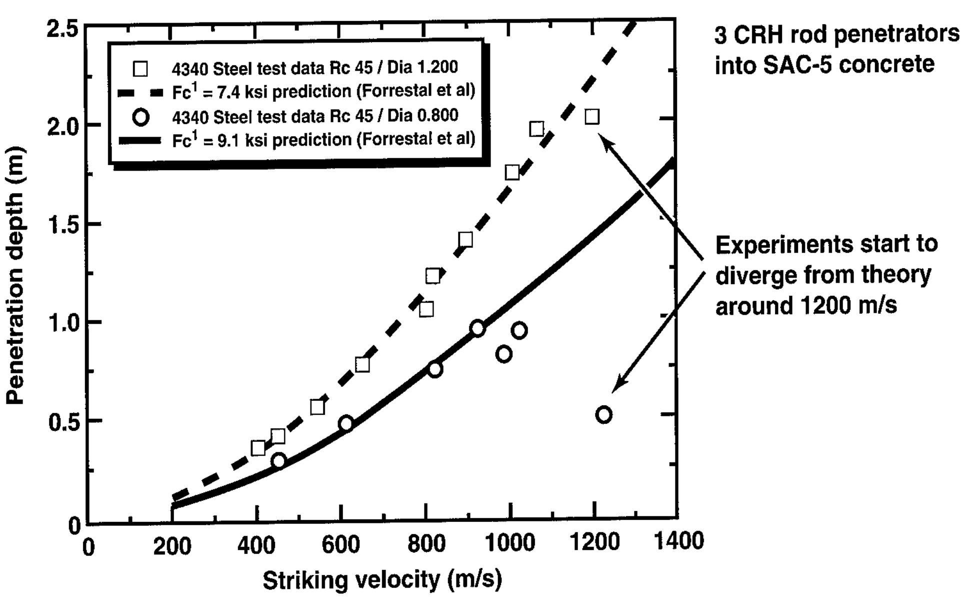


Figure 12

Enabling Technologies

As with most concepts of this type, precision targeting is a pacing technology. Precision GPS/INS guidance systems are already in use or under development. The high velocity, high performance airframe and propulsion is well within today s technology. Although high velocity penetration data is limited, we can expect substantial increases in performance up to at least 1200 m/s. High strength materials and controlled nosetip erosion techniques may substantially extend performance levels, but must be developed.

Furthermore, technologies that allow deep penetration not necessarily into the target but immediately adjacent to the target, coupled with control surfaces that will allow placement under the target by a “J ing” in the ground may prove to be highly lethal for hardened buried targets.

Conclusion

It is clear that increased impact velocities can substantially improve penetration performance. The higher speeds, rapid reaction times and long range provided by this concept can substantially increase flexibility and strike capability. The panel recommends that a high velocity penetrator technology development effort be initiated and timed to coincide with the completion of the required airframe, propulsion, and targeting systems.

2.6.3 Robotic Munitions

Concept

Future hard facilities may not be susceptible to destruction by conventional munitions. It may be desirable to develop a robotic micromunition that is capable of entering the personnel entry ports, air ducts, and/or water and sewage pipes to destroy the facility. It may fly, crawl or swim to a vulnerable node in the target. This presents significant challenges in the areas of: Micro-Electromechanical Systems (MEMS) and High Energy Density Materials for lethality and propulsion; brilliant sensors and automatic decision making to avoid obstacles and to find and kill a vital target node. In addition detailed intelligence description of the target will be required.

2.7 Air-To-Air Weapons

Aircraft-To-Aircraft

The U.S. has a great shortcoming in its air-to-air missile capability, particularly in the short range arena. The current missile, Sidewinder, has been in the inventory for over 30 years and upgrades have been minor modifications, not major improvements in its capabilities. The result has been more than a loss in competitive edge, we are now projected to lose close-in engagements. A serious effort is needed to develop a new short range weapon.

The AMRAAM may be adequate as a medium range missile today but we must be preparing ourselves for future needs. A major advancement would be to provide a multi-mode seeker, advanced kinematics, increased propulsion energy, and increased warhead lethality, but all in a smaller package. Again, this will allow a greater load-out and result in a greater kills/sortie. In summary, this must be a very agile, high performance missile. This would also present an option of carrying a longer range missile (same size as current AMRAAM but having improved capability), which means fewer aircraft needed to fly cover missions, that in turn reduces logistic problems.

An ideal capability for these future air-to-air, anti-aircraft weapons would be more than off-bore sight, it would include 180° attack and hit-to-kill capability. This allows for a smaller warhead and, therefore, missile miniaturization.

These advancements in energy, seeker and kinematic capabilities must be reached with no loss in signature qualities. In fact, reductions in missile signatures would be desirable in order to take advantage of the improvements in aircraft stealth.

Enabling Technologies

Overall improvements in air-to-air missile capability will require advanced technology in:

- Multi-mode seeker
- Guidance software for extreme kinematic maneuvers
- Increased warhead lethality
- Propellant energy increases

- Energy management (both magnitude and vector)
- Lighter weight, stronger cases
- Lighter weight, less eroding nozzles

Aircraft-to-Cruise Missile

A new missile is required to handle one of the most difficult tasks that is currently challenging the air-to-air weapons community, that is the requirement to intercept and destroy a low observable cruise missile. From the weapons standpoint, it is assumed that external observation will provide the cue that the target has been launched and its initial trajectory. The intercept missile will require:

- Long range capability
- Multi-mode seeker
- Maneuverability (60 + g's to compensate for late lock-on)
- Guidance and control to accomplish maneuvering
- Innovative kill mechanism to overcome possible large residual miss distances

Conclusion

Improvements in air-to-air missile capability is needed to overcome current superiority of enemy forces in short range air engagements. Without this, we can expect unacceptable attrition rates in any conflict.

There is a great need for a system to intercept low observable cruise missiles. This capability is totally lacking today and failure to provide it will result in unacceptable losses in personnel, equipment, and morale.

With the proper resources applied to the problem, the major technical challenges of increased propellant energy, energy management (both magnitude and vector), improved materials, and seekers should be overcome in the next decade. A key technology needed to provide the necessary missile agility is energy management. As the missile comes off the aircraft, it must be able to turn up to 180° to intercept any rear attacking missile. A short-duration, low-thrust, pulse firing of a solid propellant grain, combined with thrust vector control, will provide the turning maneuver and that will be followed by another pulse firing, at higher thrust levels, to complete the intercept.

Recommendations

These capabilities are not technically insurmountable problems. Individual technology pieces are in hand (with the exception of some of the newer, high energy materials) and integration feasibility demonstrations need to be conducted. Success will require the AF step up to the commitment of being in the air-to-air business and provide the necessary resources.

2.8 Hypersonic Munitions: Response To The Five Minute Threat

Introduction

The USAF needs an air launched missile system capable of hypersonic speeds with various terminal guidance and warhead combinations.

The reach of aircraft for missions requiring five to ten minute responsiveness is not adequate to compete with prepositioned surface launched systems such as Aegis or THAAD upper tier unless the aircraft are provided with the necessary hypersonic capability.

AMRAAM velocity of 1km/second is inadequate compared to the 5km/second class of systems that are surface launched. The inherent advantage of air mobility can be exploited if we provide high velocity weapons for air launch deployment.

This void in fundamental USAF capability can be satisfied with current solid rocket technology by building the required size for large delta-V applied to miniaturized guidance components available from SDI/BMDO efforts of the last decade. The Thrust Vector Control (TVC) will be used in conjunction with low initial thrust to give full 360° coverage from a single aircraft.

Concept

ABI is just one application of such a propulsion system. Another would be increased air defense reach by shortening an existing AMRAAM (removing its rocket motor) and treating it as a KKV on the front of the ABI's two rocket stages and used to escort bomber strike attacks or AWACS/JSTARS. A third approach would be to strike ground targets at impact velocities of 1 to 2km/second for deep penetration and damage.

The combination of high speed and 360° coverage provides the F-15s that escort the B-1 strike force the ability to engage the RF-guided SAMs which elude the normal SEAD efforts.

The initial increments of air-launched hypersonic capability will come from solid rocket propulsion systems. On a longer term basis, especially for air-to-ground missions, hypersonic missiles require the additional efficiency of air breathing propulsion. Scramjet propulsion will reduce the munition weight by a factor of two, or increase range or payload and thus should be included in the technical road map of air launched hypersonic weapons.

The ABI performance is shown in section 2.1 of this report.

The increase in ground attack reach is illustrated in figure 13 for Southwest Asia and in figure 14 for Asia. The results are dramatic and demonstrate that such air launched hypersonic weapons will significantly increase the natural effect of the mobility of manned and unmanned aircraft.

2.9 Destroying Weapons Of Mass Destruction On The Ground

Introduction

The term Weapons of Mass Destruction (WMD) is applied to nuclear, biological, and chemical weapons. Our concepts for attack on ballistic missiles in the boost phase and on cruise missiles addresses active defense against WMD in flight. Clearly it is more desirable to be able

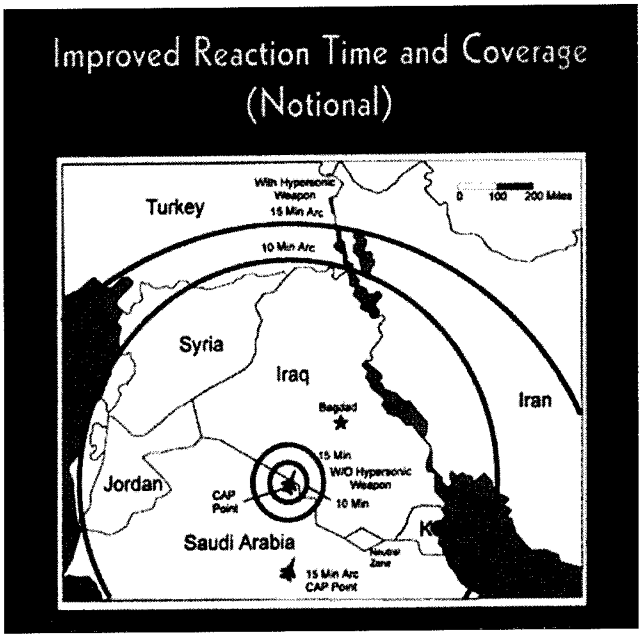


Figure 13 - Note circles and arcs represent reach distance as a function of notice time with and without scramjet capabilities (hypersonic weapons). Without scramjet: small circle 10 minutes notice; large circle 15 minutes notice. With scramjet: small arc 10 minutes notice; large arc 15 minutes notice.

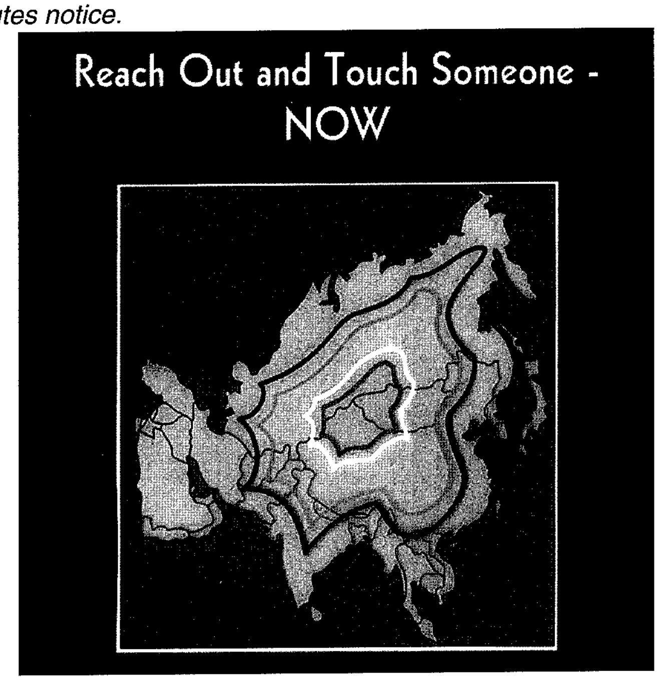


Figure 14 - Inner circle, F-16 without hypersonic weapon. Next outer circle F-15 without hypersonic weapon. Next outer circle F-16 with hypersonic weapon. Furthest outer circle - F-15E with hypersonic weapon.

to destroy these weapons on the ground (i.e., in storage) before they are launched in a delivery system.

This task is very demanding, as there is likely an attendant requirement that there be no collateral damage, that is, no release of nuclear, biological, or chemical agents as a result of the attack on the WMD. There is currently no overall weapons system concept that can robustly meet the no collateral damage requirement while assuring a high probability of destruction of the WMD. (Precise knowledge of the production and storage structures and weapon containers is a separate and very difficult challenge.)

Concept

One promising direction for munitions research is in thermoflux materials to create very high long duration local temperatures to destroy chemical and biological agents. Another approach is to create a major delay in the enemy's use of their mass destruction weapons. A current program has developed a viscous, very sticky foam which could be generated in a storage vault from a penetrating warhead. Such foam would cover or fill the room and render the WMD unusable.

We recommend a focused research program in these areas, with specific milestone to identify progress. This work needs to be coordinated with the chemical and biological defense community.

3.0 Enabling Technologies and Capabilities

As we developed our lists of capability needs and concepts, certain key enabling technologies and capabilities emerged. In identifying these critical technologies the Munitions Panel established the following selection criteria: (1) the technology should be critical to a broad range of weapon systems, (2) the commercial sector may develop the technology, but not at the required pace or with the specific characteristics required or, (3) the technology has a unique DoD application. The following technologies and capabilities have such wide range of applications and are so critical to the future mission of the Air Force that the Panel felt these should be specifically highlighted.

3.1 High Energy Density Materials (HEDM)

Introduction

The design of High Energy Density Materials (HEDM) is a core competency technology base within the national defense assets. This competency resides within the DoD and Department of Energy laboratories. While HEDM do have commercial applications, the leading edge of the technology, which represents the technological edge of the national defense infrastructure, is based upon the performance objectives of military applications. The high energy density requirement reflects the military objective of light weight, minimal volume capabilities and supports mobility and rapid response.

This technology impacts a wide range of munition metrics including warhead lethality and the kinematic performance of missile systems. Two major means of improving the capability of a munitions system are to increase the available energy of the propulsion unit (provides longer range, shorter time to target, smaller system, greater kinetic energy for penetration) and to increase the available energy of the warhead (provides increased lethality, smaller system). Both means may be met by exploiting advances in the area of high energy density materials.

Tremendous advances in computational chemistry capabilities are providing researchers the opportunity to rapidly perform the theoretical studies which guide the selection of new materials. Computations also assist in selecting synthesis pathways, ingredient identification/characterization spectra, and dynamic stabilization techniques. This computational capability provides a great improvement to the old empirical approach which led many synthesis research efforts down a long, tortuous path before it was determined to be a dead-end path. The revolutionary approach is a first principle based design approach to understanding the development of high energy density materials based on their use in specific applications.

Additional technologies which address the manufacturing of critical ingredients are having a large impact on the engineering design of intermolecular systems and the controllability of energy release processes, as well as the overall energy packaging characteristic, whether considered from a weight or volume point of view. Long term technologies which address the fundamental concepts of energy packaging for use in military weapons have made some major advances. The objective of these technologies is to increase the energy packaging by one to two orders of magnitude. Among these concepts, "extended solids" has moved into experimental work and have validated the theoretical foundations of earlier work.

Munition Propellants

Smoky (high signature) propellants generally consist of a rubber binder, aluminum fuel, and Ammonium Perchlorate (AP) oxidizer. These propellants have been around for over 40 years without any major changes (generally the same fuel and oxidizer with changes in additives to control ballistics and in the binder to improve mechanical properties).

Reduced smoke propellants have the aluminum removed and were created to eliminate most of the weapon's visible contrail (caused by aluminum oxide particulates). Removal of the aluminum results in a loss of energy. These propellants are used in Sidewinder, AMRAAM, HARM and Maverick.

Minimum smoke propellants do not have aluminum and they have also exchanged the AP for oxidizers with no chlorine (since chlorine tends to form faint contrails of hydrochloric acid). These replacement oxidizers are also generally of lower energy. This class of propellant is used in Hellfire.

Obviously, both reduced and minimum smoke propellants gain their lower visible signature benefits at the expense of energy. The challenge to propellant researchers is to exceed the energy content of smoky propellants without sacrificing the low visibility characteristics of reduced or minimum smoke propellants. This change in propellant composition must also be accomplished without a sacrifice in cost or hazards/safety properties.

One of the most promising new oxidizers is Ammonium Dinitramide (ADN). This material has greater energy than any oxidizer in the current U.S. inventory. In addition, it contains no chlorine (i.e., will not produce a secondary contrail). It has a specific impulse increase of 7 seconds over AP in a non-metallized propellant and 11 seconds over AP in a smoky propellant. ADN is a salt that derives most of its energy from the two nitro groups attached to a single amine nitrogen. ADN was synthesized by SRI in 1988. When the patent was published, the Russians openly stated they had prepared ADN many years ago and actually had it deployed in systems for 20 years. That application had earned the responsible Russian scientists the Lenin Award and had been protected at the same level as our Manhattan Project. The two potential problems with ADN are cost and safety.

Another high energy oxidizer is CL-20 which derives its energy from a strained ring structure with single nitro groups on amine nitrogens. This particular molecule was first made in the U.S. by a team of Navy researchers at the Naval Air Warfare Center at China Lake. CL-20 has no chlorine. It is less energetic than ADN but is 8 seconds higher in specific impulse than ammonium nitrate, the currently used non-chlorine oxidizer.

If either of these oxidizers proves to be acceptable, it will solve the major problem encountered when reduced observable systems were developed (e.g., sacrifice of energy).

For weapon systems and space boosters that do not require the elimination of aluminum oxide particulates from the contrail, a major energy increase is possible if aluminum hydride is used as the fuel in place of aluminum. Theoretical computations are underway on many other potential propellant ingredients that contain increased energy due to strained chemical bonds or unusual combinations of atoms.

Energetics For Warheads

The relationship between energetics and warfighting capability is identified as the ability to use stored chemical energy to destroy selected targets. This process may be divided into the following steps:

- Energy storage
- Trigger for release of energy
- Partitioning
- Transport
- Coupling
- Activate damage threshold

The prompt conversion of solid high explosives to gaseous products is the result of detonation. Conventional wisdom in energetic materials associates target defeat with the production of gas which is the working fluid that transports and couples the explosive energy either directly to the target or uses metal as an intermediary in the form of fragmentation, jets, or explosively formed penetrators. The promptness of the detonation process limits the ways that the stored energy can be used to disrupt the function of targets.

Shift in Paradigm

U.S. defense application has been narrowly focused on insensitive energetic materials for Insensitive Munition (IM) applications for the last decade or more. Insensitivity remains a critical issue and programs related to the IM objective must be continued. However, an expansion of the technological objectives of HEDM to focus on performance is needed to recover lost opportunities in the areas of:

- Molecular synthesis
- Formulation chemistry
- Detonation and combustion chemistry
- Detonation and combustion physics

Material design technology based in quantum chemistry and solid mechanics are defining revolutionary, first principle approaches to the design of HEDM. These technologies offer a "leap ahead" rather than a "catch-up" approach to moving the national HEDM program into the future.

Tunable Energy Release Technology

Recent research has identified the ability to control the reactive power of a special class of HEDM which have come to be known as Metastable Interstitial Composites (MIC) from a few kW/cc to tens of GW/cc. They are a branch of the family of energetic materials known as thermites and more recently Ballotechnics. These MIC materials provide the opportunity to tune the energy release characteristic of the weapon to match the requirements of specific damage

processes for a wide variety of targets. In addition to the advantage of tunable energy release, these materials also increase energy packaging in most cases.

MIC materials consist of two or more chemical species that are exothermically reactive with each other. Specific examples include Al/MoO_3, Al/ Teflon, and Al/$KClO_4$. (See figure 15.) This means that the energy storage is intermolecular as opposed to intramolecular, as it is in conventional explosives such as HMX and RDX. The key to the tunability of MIC materials is the ability to manufacture mixtures with controlled intimacy. One of the enabling technologies has been the production of ultra-fine grain Al powder using RF plasma torch techniques.

Consistent particle size and topology in the nanometer range have been produce. In order to control the physical intimacy of the constituents of the MIC materials, processing methods have been developed based on forming suspension and solutions. The resultant materials have been subjected to various stimuli commonly used in safety assessments of energetic materials, e.g., impact, friction, and electrostatic discharge.

The use of MIC materials as a tunable energy source could provide a mechanism for thermal attack against biological threats at the manufacturing or storage point. A hard structure penetrator loaded with MIC would be used against these targets. They also offer the possibility of enhanced target defeat because of enhanced explosiveness within a target.

Enhanced Energy Storage

Revolutionary energy storage systems based on metastable solids formed from high pressure phase transitions have recently progressed from the realm of theoretical calculations to experimental recovery from diamond anvil experiments and appear to be promising.

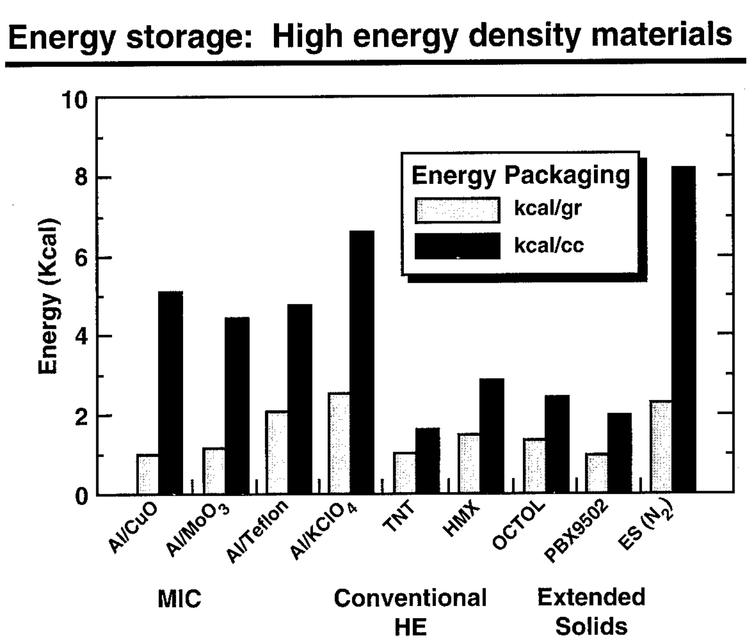


Figure 15

Conclusions

The U.S. is far behind Russia in the exploitation of advanced chemistry/physics applications in propellants and explosives. At a time when our investments were shrinking, their investments were still growing. As a result, the Russians developed many new, high energy solid ingredients, both fuels and oxidizers, while we were still using those materials that were already developed and well understood. In addition to the solid ingredient advantages, their progress in liquid ingredients is superior to ours. Whereas we accepted a hydrocarbon fuel that was low cost and readily available as a distillation fraction from the petroleum industry, they studied the combustion characteristics of hydrocarbons and selected specialty chemicals that were of higher energy than our RP-1 and burned more efficiently.

There are many needs for advancements in energy of propellants and explosives. To penetrate and destroy deep or hardened targets requires greater kinetic energy from the propulsion unit and higher energy release from the warhead. These advancements are also needed to intercept and destroy both cruise missiles and theater ballistic missiles, to provide air-to-air missile superiority and for long range, precision attack (no collateral damage) on critical targets.

These capabilities are important to the AF because they provide the ability to reach out anywhere at any time to deliver a strong message to the enemy and to protect friendly forces. The expected benefits are air superiority and denial of any form of retaliation.

Most of the necessary advancements in propellants and explosives can be demonstrated within the next ten years. There are even greater increases (as presented in the Materials Panel Report) that will be available after ten years. An example of this is cryogenic solids (e.g., boron atoms imbedded in solid hydrogen matrices). Success in this area will require a dedicated effort on the part of DoD because the greater payoff will be in military applications, not commercial ones.

There will not be a large commercial application for advancements in explosives (outside of the mining industry) or in munition propulsion, but there will be a tremendous payoff in the commercial space business for propulsion capability improvements. With the current and anticipated boom in the satellite business, increased payload capability will have tremendous payoffs because the most important factor is cost per pound of payload delivered to orbit.

Recommendations

Provide the resources needed to conduct basic research and exploratory development efforts (6.1 and 6.2 projects) necessary to catch and surpass Russian capabilities.

The next twenty years will see significant improvement in the fundamental understanding of energy storage in HEDM and it's impact on conventional weaponry. The new materials will give significant range enhancements along with improved safety. The new explosives can empower reducing the size of warheads to either make smaller the rocket or increase the range and/or velocity. The challenge is the identification of the process to ensure early exploitation of these materials to satisfy a wide range of Air Force mission needs.

3.2 Battle Damage Assessment (BDA)

Introduction

The stand-off capability enabled by the next generation of smart weapons, makes the development of effective stand-off BDA essential. Accurate, prompt BDA data is needed to assure that critical targets are killed, to minimize the numbers of weapons per kill, to divert unneeded second waves and to provide retargeting data to smart weapons to change tactics or to enhance their ATR effectiveness.

Concept

Two alternative deployment strategies can be adopted for BDA, long-range and close-range. Long-range damage assessment uses data from sensor platforms such as satellites or UAVs. These can generally only provide low resolution BDA data and operations can often be severely inhibited by cloud cover or smoke. Close-range sensors can provide more specific BDA data. However, close-range operations place the airborne sensor platform or the deployment platform for ground sensors at risk.

To provide close-in BDA, the best solution is offered by an expendable, covert platform that can be deployed at close-range to the target prior to the strike. An effective and inexpensive method of sensor deployment is to use the munition itself to deploy expendable BDA sensors.

Low cost, miniaturized, glider platforms have been developed and demonstrated that could be applied to BDA. As illustrated in figure 16, a miniaturized BDA payload can be carried on-board a smart munition for deployment in the target area. This would remain on station, while slowly descending over a target area allowing data to be collected during and following a strike. The three technology areas that are key to the development of this low cost, BDA system are: low cost deployment platforms, miniaturized sensors and telemetry links.

All-aspect BDA Concepts

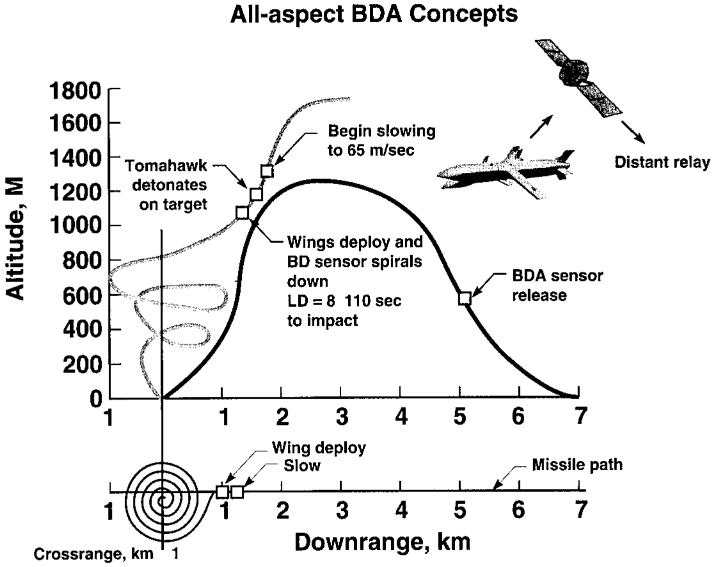


Figure 16

With the munition deployed platform, the BDA sensors get a "free-ride" with the munition or submunition and can be deployed at a high altitude near the target area. Gliders can achieve flight ranges in excess of 150 NM when deployed at 40,000 feet with a 20:1 glide ratio. On-board miniaturized GPS and Micro-Electromechanical (MEM) inertial sensors can be used to provide autonomous flight control and guidance to a target area. Because of the small size of the payload, the glider will have a very low acoustic, visible, thermal, and RCS during its descent.

Hughes Missiles has demonstrated a miniature glider, the "Coaster" that includes an IR or visible imaging camera and a UHF satellite telemetry link in an 8 pound payload suitable for deployment from a submunition. Aerovironment Inc. has developed an air deployed X-Glider platform to provide a low cost flight system for use in the stand-off deployment of sensors. They also manufacture the Pointer, a low cost reconnaissance UAV which carries commercial video electronics.

Commercial advances in electronics can be expected to further reduce the size and cost of sensor and telemetry electronics. This will allow alternative deployment platforms, such as those currently used in commercial meteorological sensing to be carried by miniature munitions. Small, low cost, sensor telemetry packages have been developed for deployment by aircraft or small rockets (dropsondes and rocketsondes). Low cost parachute and autorotating designs have been used to provide braking for small electronics packages typically weighing 100 to 300 gms. Dropsondes have been developed for deployment by high-speed aircraft, such as the F-4, providing braking to vertical drop rates of 3-5 m/s (at sea-level). The small size and low cost of these platforms would enable BDA sensors to be carried on-board miniaturized smart munitions or submunitions.

A munition deployed sensor platform provides a low cost, effective method of placing BDA sensors close-in to the target. Sensor technology has been addressed separately by the Sensors Panel and can include video, IR, and audio sensors. Miniaturized telemetry links that can network sensor data have also been addressed elsewhere, they can be used for collecting and relaying the sensor data.

Recommendation

Miniaturized, low cost, guided sensor platforms should be developed that can be deployed from smart munitions to provide BDA data.

3.3 Munitions Counter-Countermeasures

Introduction

Another challenge that will assume increasing importance is assuring the performance of guided munitions in an environment with heavy countermeasures. One can expect advanced countermeasures to proliferate to the third world; the Gulf War highlighted the importance of countering U.S. air-to-ground guided munitions. Countermeasures to air-to-air guided missiles (e.g., flares) have been widely deployed for some time. One important historical lesson about countermeasures is that every system can be countered in some fashion and potential enemies will continue to field new countermeasures. Thus, developing Counter-Countermeasures (CCM) for existing munitions should be a continuing activity of the Air Force.

Countermeasures to guided munitions fall into several classes, each class of which has its own characteristic CCM. We review these classes and their CCM. The first class is active defense, that is, shooting the munition. Passive defenses attempt to make a hit tolerable; examples include armor, underground structures, and redundant hydraulic lines on an aircraft. Signature control seeks to deny a munitions seeker the signature it requires to guide. Although camouflage is as old as warfare, modern signature reduction technology, primarily applied to aircraft and surface vehicles, is highly complex. Currently likely adversaries cannot employ signature reduction effectively, however efforts at signature reduction in Europe and Russia suggest we will need to deal with this technology. A related countermeasure is the use of obscurants to hide the signature. These can be either generated (like smoke) or natural (like clouds). The widest class of countermeasures is inband ECM. These are systems that attempt to deceive or blind the seeker using energy or signals within the seeker's pass band. This includes many well-tried techniques like noise jamming, flares, and gate-stealers.

Earlier we discussed development of ECM weaponry concepts to incapacitate the enemy's electronics. However, the increasingly high reliance of the DoD on electronics technology for their communications, computing and information processing, avionics, guidance, navigation, and control, and command and control systems makes DoD warfighting capability even more susceptible to ECM countermeasures. This is especially an issue with the increased reliance on commercial electronics which, although inexpensive, do not have the countermeasure hardness that previously has been available in some special military electronics. Technology has sufficiently progressed in the past decade outside the U.S. to make development of practical weapons using ECM to upset or substantially degrade these electronic circuits very likely. An enemy countermeasure with this capability could cause major disruption in our modern warfighting capability if successfully deployed against our systems. This situation should make the development of CCM to this capability a priority activity. This should include as a minimum: programs to understand and model the phenomena; evaluation of susceptibility of current systems to ECM; and development of hardening techniques including shielding, design approaches, and exploitation of new materials and processes with lower susceptibilities.

In addition to countering the munitions, an adversary can attempt to counter other components of the weapon system such as acquisition and fire control sensors, and the launch platform. While dealing with these countermeasures is not a munitions issue, the vulnerability of the launch platform leads to a preference for launch and leave weapons with as large a standoff range as possible.

Concepts

When we consider CCM, we must remember that the countermeasure operates as part of a system. This may contain, in addition to the countermeasure itself, a deployment vehicle, and Acquisition Pointing and Tracking (APT) system, and intelligence and cueing support. Disrupting any of these components can defeat the countermeasures. In particular, since many classes of countermeasures require APT systems, these can be attacked by reducing the signature of the munitions. For air-to-air munitions, the key signatures are the IR and UV plume and the body IR signature. IR and RF signatures are key for air-to-ground munitions. For optical munitions the Optical Augmentation signature is important. We will consider CCM for air-to-air and air-to-ground separately.

Air-To-Air Missiles

For air-to-air missiles, passive defense is not a viable approach. Aircraft carry limited armor, and warheads are now, and presumably will continue to be, designed for maximum lethality.

Active defense against air-to-air missiles is not currently done, but presumably an active defense would be a self protection missile (see section 2.3). One can either defeat the APT, or outmaneuver the interceptor which is likely to be marginal. Defeating the APT would be done by reducing the signature of the missile.

There are a number of types of inband ECM, each with its own CCM. For IR missiles, the conventional ECM, like flares and flash lamps, are designed to defeat reticle (and pseudo imaging) seekers. New seekers, like the AIM-9X, will be staring imagers; this will defeat these countermeasures. The inband countermeasures to imaging seekers use high power lasers. CCM techniques include defeating APT systems, careful optics design to reduce scatter, filters to block the laser lines, and home-on-jam.

For radar seekers there are several classes of important inband ECM. The first class are devices like gate stealers, that attack the tracking circuitry of the missile without angle deception. These are countered by traditional signal processing CCM. The next class is expendables. Passive expendables like chaff and blivets are rejected by Doppler; more advanced forms, like illuminated chaff and active expendables are also in use. These can be rejected when they separate from the aircraft. The next class is high power systems like Cross Eye and Cross Pole that disrupt or break angle track. These can be countered by signal processing techniques or home-on-jam.

The final class is endgame angle deception countermeasures such as towed decoys and terrain bounce. This is the most difficult for CCM since the Doppler can match the target, and the false target stays with the target. These countermeasures are currently being deployed outside the U.S. including systems on cruise missiles. The most primitive implementations can be defeated by signal processing, like range gating, but more advanced implementations will have to be discriminated in angle. This can be done by either super-resolution or a dual mode seeker, with the second mode (probably IR) having enough angle resolution to discriminate. The latter is the approach taken by the Navy s Missile Homing Improvement Program (MHIP). Super-resolution techniques seem promising and will likely work for conventional aircraft. For the signal-to-noise typical for cruise missile engagements a super-resolution seeker will have to move to Ka band. The Air Force should pursue dual mode and super-resolution seekers.

Air-To-Ground

For air-to-ground munitions passive defense, burying or armoring the target is a key countermeasure. Responses are discussed in section 2.6 on Buried Hard Targets. Active defense against cruise missiles is a subset of the air defense problem. Active defenses against bombs are not a serious threat; it is too hard to kill something that is already falling.

Signature reduction of ground targets against SAR radars or imaging (passive or active) optical sensors is not practical, except in limited circumstances. The IR signature of a vehicle can be reduced enough to defeat non-imaging IR seekers, but these are becoming obsolete.

The related area of obscurants is a key countermeasure. Operating under the clouds or smoke will defeat our current PGMs which are optically guided as was highlighted during the Gulf War. There are several candidates for seekers that can operate through these obscurants while still providing 10 feet accuracy. One choice is to continue using optical munitions but increase the agility of the airframe so that it can divert to the target when it can detect it through the obscurant (say 100m away). For all weather precision seekers several options make some sense. RF seekers are the natural choice for penetrating weather and smokes, but have some drawbacks. Real beam seekers must either operate at W band and higher frequencies, where components are not readily available, or do such large amounts of beam splitting that the signal processing required has not been fully developed or tested (or both). Synthetic aperture seekers have been developed and tested captive carry in the ASARG program. There are, however, a number of difficulties with SAR seekers. The primary one is that to get accurate resolution for the SAR, the munition must move cross-range to the target. Thus, the munition will have to fly a dogleg toward the target and must go inertial for the last leg. This means the accuracy is degraded by INS drift, and that it is more suitable for cruise missiles than penetrating warheads. There are also cost and targeting issues. Another approach has been to put the SAR on an aircraft, and use that to direct the bomb, either by command guidance or semiactive means. This allows both the SAR and the munition to fly their optimal paths, but the SAR measurements will be made at a further range, and so higher resolution must be achieved, which is a strong technical challenge. GPS may be a possibility either using a differential or relative scheme, but GPS is vulnerable to jamming in the terminal area. To achieve 10 foot accuracy with current low cost IMUs requires the GPS lock to be maintained so close to the target that it is probably not cost effective. However, dramatic improvement in either low cost IMU performance or adaptive antenna performance might make this an attractive option. TERCOM can be used to update a munition IMU, and the mission planning problems, which are historically severe, have been addressed by the ITAG program, which uses an accurate altimeter and DTED at about 1 meter accuracy. An onboard computer uses the stored map to find its location (within a few seconds) and plot a path to its target. This would be a very attractive solution. If we can produce sufficiently good DTED world wide; the principal proposal here is some sort of interferometric SAR.

The inband ECM, of course depends on the nature of the seekers. One approach is to use a mix of seekers so that no one countermeasure is effective against all of them. The adversary will be discouraged from deploying systems that operate only against a fraction of the potential munitions, and we have some munitions that will function despite the countermeasures.

Specific countermeasures of concern are GPS jamming, laser jamming of optical munitions, jamming of control links, decoys for laser guided bombs and paint schemes to fool imaging IR seekers. GPS jamming is of particular importance since GPS systems are becoming ubiquitous. Because of the importance of GPS it is treated in a separate subsection.

To defeat link jamming one can use more jam resistant links, including more use of spread spectrum techniques. To beat deceptive paint schemes, for example a paint that is uniform in visible bands but a checkerboard pattern in the 8-12μ region, we can use IR (that is inband) imagery for targeting or by better algorithms incorporating machine intelligence. To harden laser guided bombs against repeater decoys like the one being marketed be GEC-Marconi, the Air Force should use the PIM codes available for PAVEWAY III. To defeat more sophisticated

decoys the Air Force should consider the improved ECCM of the Army s Hellfire II. To beat laser jammers one can reduce signatures of munitions to defeat the APT systems, or employ classical laser hardening techniques. In the long run any system will be susceptible to some form of inband jamming. The Air Force should keep a variety of seekers in inventory, and should pursue a program of steadily improving the CCM capabilities of its munitions.

Recommendation

- The Air Force should use advanced AJ for its GPS receivers and should improve links between aircraft and munitions.
- Pursue Air-to-Air seekers that can intercept cruise missiles employing terminal endgame countermeasures. Follow Army and Navy multimode seeker programs.
- Maintain a mix of air-to-ground seekers and a CCM program for them.
- Develop Precision Guided Munitions that operate through smoke and weather.
- Pursue reduced signature munitions.

3.4 GPS Counter-Countermeasures

The low power of the satellite signal broadcast makes GPS particularly susceptible to jamming. Pulse, CW, broadband noise and spoofers can all disrupt precision navigation operations that rely on GPS.

In figure 17 and table 1, the minimum operating range from a GPS jammer is illustrated for conventional and advanced GPS receivers. A 1 kilowatt jammer, for example, will disable existing GPS receivers over distances up to nearly 100 kilometers.

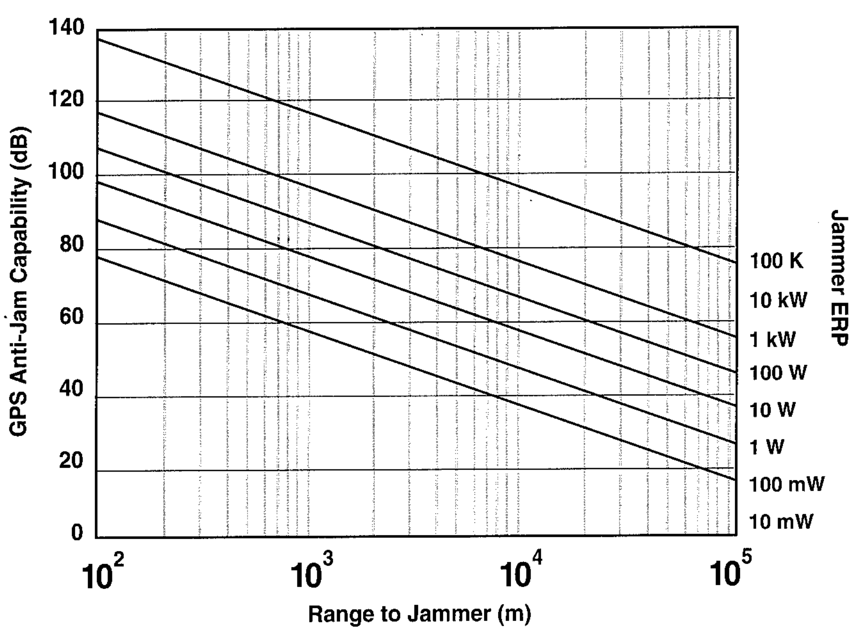


Figure 17

Table 1

Radius of Protection Provided by Various Single Jammers

GPS Receiver Type	Highest Tolerable J/S (dB)	Jammer Effective Radiated Power	Radius of Protection (km)
Current Military Receiver	54	1 W	3
		10 W	9.5
		100 W	30
		1 kW	95
		10 kW	300
Advanced Receiver	68	1 W	.6
		10 W	1.9
		100 W	6
		1 kW	19
		10 kW	60
Current Military Plus Nulling Atenna	84	1 W	.1
		10 W	.3
		100 W	1
		1 kW	3
		10 kW	10
Advanced Receiver Plus Nulling Antenna	98	1 W	.02
		10 W	.06
		100 W	.2
		1 kW	.6
		10 kW	2

There are two different classes of approaches that can be taken to counter GPS countermeasures. The first is to enhance the GPS receiver and antenna design to improve the J/S margin. The second is to provide a back-up capability to allow precision targeting when GPS is disabled close-in to a jammer.

Enhanced A/J Receiver Performance

Sophisticated anti-jamming techniques under development for GPS can offer significant improvements in J/S over the existing fielded equipment. Improved antenna design, digital filtering and signal processing techniques that take advantage of advances in electronics can provide cost-effective solutions for next generation military GPS receivers, as illustrated in table 1.

Potentially, anti-jam receivers that can operate with J/S up to 120 decibel could be developed and put in operation within the next five years. With 120 decibel J/S margin, operations can be sustained with relatively high power jammers (e.g. 1 kilowatt) to within 100 meters of the jammer.

Back-up Navigation Sources

Since even the most sophisticated A/J GPS receivers are susceptible to high power jammers close to a target, a back-up navigation system is needed for precision close-in navigation.

Back-up navigation can be provided by an on-board inertial system, from another unjammed radionavigation source, or by using data from imaging sensors on the munition.

Micro-Electromechanical IMUs

Micro-Electromechanical (MEM) Inertial Measurement Units (IMUs) are under development that will provide a low cost, single-chip autonomous navigation solution. As illustrated in table 2, in the near-term, only low grade navigation systems are feasible (Model I). When integrated with GPS, precise navigation can be provided over only short periods of time following GPS drop-out. (See figure 18.) In the future, some of the advanced MEM sensors under development, particularly those involving superconducting materials, could provide performance equivalent to existing Ring-Laser-Gyro (RLG) inertial systems (Class III or IV in figure 2).

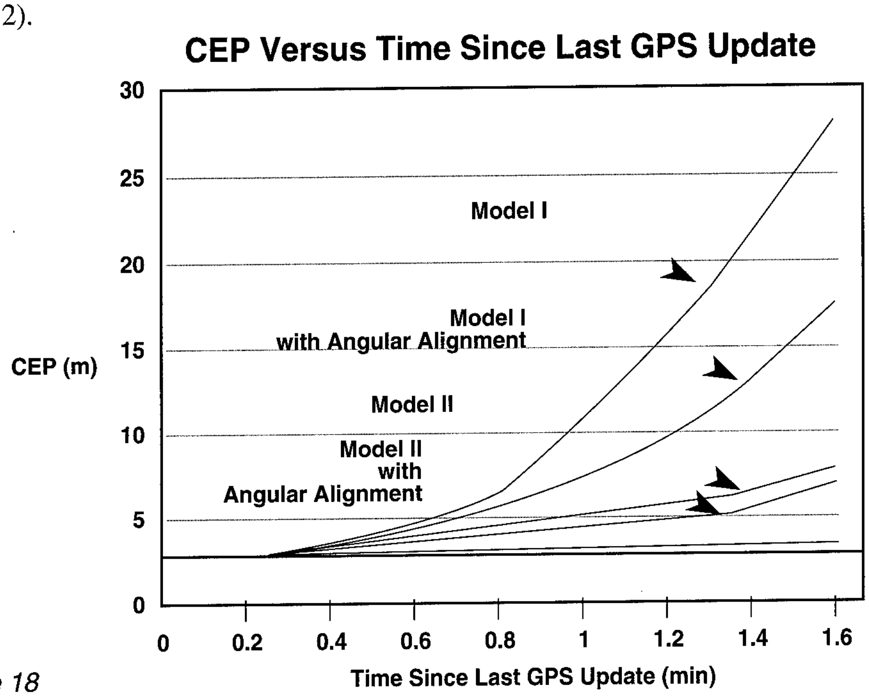


Figure 18

Table 2

Hypothetical IMU Models			
Model	**Gyro Drift Rate**	**Estimated Cost in Large Qty (CY 2000)**	**Representative Example**
I	**10°/hr**	**$1K**	**Expected Near Term Micromechanical IMU**
II	**1°/hr**	**$2K - $4K**	**Advanced Micromechanical IMU**
III	**.1°/hr**	**$20K - $50K**	**.IFOG5 IMU**
IV	**.01°/hr**	**$100K - $200K**	**High Performance Aircraft IMU**

Back-up Radionavigation Systems

Precision navigation can be maintained close-in to a GPS jammer by using alternative radionavigation sources as a back-up. Any broadband signal broadcast can provide pseudo-ringing data for navigation if it is synchronized to GPS time, either directly in the data modulation or through differential corrections in the data for the signal time offset.

Radiolocations techniques have been demonstrated by the civilian community using triangulation and trilateration from such diverse signals as cellular transmitters, FM radio stations and TV broadcasts. Accuracies down to 100 meters have been demonstrated. Significant improvements in accuracy are possible when using broadband signals broadcast from geostationary or LEO satellite systems, such as direct broadcast TV, Inmarsat, Iridium, or Teledesic. Signals broadcast from commercial or military satellites, or from UAV platforms as illustrated in figure 19, can provide an adjunct or back-up service to GPS over a theater of operations.

Commercial technology advances will allow low cost, miniaturized, frequency diverse receivers to be developed that can process different signal types over a broad range of frequencies. Multi-mode receiver designs that can use alternative signals as radionavigation sources provide an effective counter to GPS countermeasures.

Broadcast Signals to Backup GPS

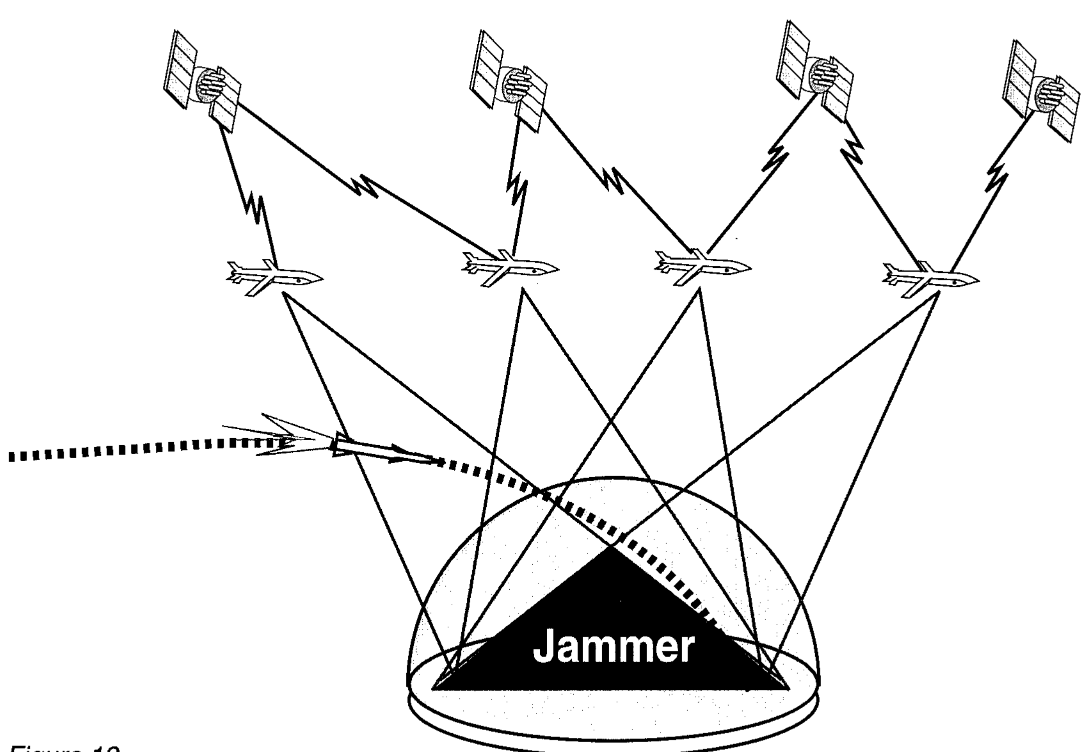


Figure 19

Imaging Sensor Guidance

Future smart munitions will use low cost, miniaturized imaging sensors, such as video or IR lasers to provide Automatic Target Recognition (ATR). These sensors can also support guidance and navigation in the vicinity of a target. A database of recognizable features can be used to update the munition's location and provide guidance to the actual target. This terrain recognition capability would offer a low cost navigation capability close-in to a target when GPS is jammed.

Conclusion

The following techniques are recommended as having the best long-term potential for meeting GPS ECCM needs:

- Advanced digital, multifunctional receivers be developed that can directly acquire and track both the PPS GPS signals and also broadband signals at other frequencies from sources that can be used for radionavigation.
- Commercial or military geostationary of LEO satellites or UAVs can be used to broadcast high power, synchronous broadband satellite signals over target areas to provide a back-up capability for GPS.
- Precision micromechanical IMUs be developed and embedded with the receiver and antenna systems to improve A/J performance and provide back-up navigation in the event of jamming.
- Miniaturized antenna elements be designed for installation on small munitions to provide low cost, adaptable A/J antennas.
- Terrain recognition navigation and guidance algorithms should be developed for future smart munitions with imaging sensors.

3.5 Identification Friend or Foe (IFF)

Introduction

Warfare in the future will be increasingly complex. We may be involved increasingly in coalition warfare and what is termed the non-linear battlefield; i.e. highly dispersed troops engaged in individual actions. In addition, we will see ever increasing diffusion of "First World" technology into the "Third World" such as SWA and the Orient. This could then likely lead to identical "engines of war" facing each other, i.e. T-72 tanks or Chieftain tanks on opposing sides of a battle. To eliminate our own or friendly fatalities in such battles, a cooperative IFF technology is required, especially in close air support missions. An IFF system must be all-weather, all environments, including the fog of war, and be non spoofable.

Future weapon systems need to be designed to handle the following scenarios:

- Forces operating cooperatively with non-U.S. air and ground forces.
- Friendly and enemy forces having common ground equipment and/or aircraft.

- Stand-off engagement of targets using "smart" weapons.
- Prevention of collateral damage of U.S. and friendly ground forces and aircraft from U.S. or friendly forces.

Concept - Beacon-Based IFF

With beacon-based technology, friendly-forces are equipped with coded transponders that can be interrogated when targeted by weapon systems. The U.S. Army is the lead agency for this effort and is investigating RF, IR and laser tags to develop an all-weather, secure IFF capability. A secure LPI system is required so that the beacons or tags do not place forces at risk by providing potential targeting information to enemy forces.

A major disadvantage with this approach is that it requires special equipment on both the weapon or aircraft firing the weapon and the potential "friendly" target. This results in a large scale security and logistics management issue. Unless a multi-national, multi-force IFF standard is developed, it will be unlikely that this system could be operated cooperatively with non-U.S. friendly forces.

Concept - Cooperative IFF

With this implementation, the IFF function is managed by the central command facility, using existing communication channels and location coordinates provided cooperatively by friendly forces.

The Cooperative IFF system is similar to the Autonomous Dependent Surveillance (ADS) system under development by the FAA for air traffic control and automatic collision avoidance. In this system, all participants periodically report their current location and route to a central command facility. This maintains a situational awareness database of all friendly forces. Reporting can be done automatically using GPS either periodically, on-demand or manually for covert operations. Reporting can also be from verbal status reports or mission plans if no other data sources are available. Since the reporting is performed cooperatively (i.e. under control of the reporting party), and queries can only be used to verify a target location (not identify the current location of a friendly participant), there is no possibility of this system inadvertently disclosing friendly force locations outside of the command centers, where the data would be available for situational awareness.

The technology exists for IFF verification to be performed automatically through a transaction like a commercial "credit card check." Once a target has been acquired, a query can be sent to the central database to immediately verify that friendly forces are not at the target location. Commercial technology has been developed that executes this type of transaction within seconds using conventional communication links. Technology can be leveraged from the Geographic Information System (GIS) industry for geographic data management, and from the telecommunications and financial community for secure data management and high-speed queries and networked data access. Rapid technology advances in these areas can be expected to continue in the commercial sector driven by the high growth financial, telecommunications, and transportation geographic data management industries.

Enabling Technologies

Enabling technologies that can be leveraged to tackle these challenges are:

- Secure two-way Low Probability of Intercept communications.
- Precision location for situational awareness.
- Low cost, miniaturized commercial electronics.
- Large scale geographic information and database management systems with sophisticated, high-speed query and data access.

Recommendation

It is recommended that cooperative IFF systems be investigated using commercial geographic data management tools integrated with joint services command and control networks.

3.6 Propulsion Energy Management

Introduction

In order to get the high maneuvering capability many of the future missile concepts require, real-time control of the propulsion energy will be needed. This includes both the magnitude of the thrust and the vector of the thrust. This technology will provide a weapon system capability to:

- Come off the platform with a high thrust to attack front-quadrant targets in a short time-to-target.
- Come off the platform with a low thrust and use vectoring to provide quick turnaround to attack a target in the rear. Once aligned with the target, the rocket motor will shift to high thrust for a quick intercept.
- Use the improved kinematics in the end game against a highly maneuvering target.
- Use the improved kinematics to impart greater kinetic energy to a penetrating weapon.

Concept - Thrust Magnitude Control (TMC)

Pulsing with solid propellant grains has been demonstrated. This allows a motor to fire one pulse, coast, fire the next pulse, coast, and fire the next pulse or the coast periods can be skipped to provide a continuous thrusting. Other concepts are in various degrees of development and also have a good promise of meeting thrust magnitude control requirements. One approach is the class of propellants called gels. They may be pumped like liquids which provides for throttling. Another approach, which also provides throttling capability, is hybrid propulsion. This system uses a solid grain (fuel) and pumps a liquid oxidizer over the fuel. This concept is very promising as a low-cost, low-hazard, strap-on booster for space launch and studies are currently underway to evaluate payoffs in the air launch arena. Pintels may be used to move in and out of the nozzle throat to modulate the motor operating pressure, thus the thrust. Engineering design studies will determine which TMC approach is best suited for each missile concept.

Concept - Thrust Vector Control (TVC)

Many TVC techniques have been demonstrated in the past (e.g., jet vanes, jet tabs, moveable nozzles, and liquid injection in nozzle exit cones). Also, the Munitions Directorate of Wright Laboratory has a current program investigating TVC. However, to get the required turn rates of the systems under consideration will require adaptation of more active reaction/attitude control systems in use in spacecraft or in development by BMDO for use in KKVs. The BMDO work is particularly critical because of their emphasis on miniaturization. Again, engineering design studies will determine which TVC approach is best suited for each missile concept.

3.7 Micro-Navigation Sensors

Introduction

To perform their mission, future precision munitions will require, in addition to LADAR, miniaturized, low cost, precision, autonomous navigation systems. This can best be accomplished through a combination of GPS and inertial sensors. Enabling technologies will include Multichip Module (MCM) GPS receivers, and MEM Inertial Measurement Units (IMU).

GPS

Single-chip GPS sensors have been demonstrated for commercial applications that employ MCM technology to reduce the size and increase the functionality of the receiver while still using off-the-shelf components. These techniques can also be applied to military receivers to allow them to include advanced A/J filtering and rejection techniques in a package suitable for installation on a micro-munition.

MCM packaging technology will be pursued aggressively by the commercial community as it supports highly sophisticated, low cost, miniaturized electronics for large quantity markets. The DoD unique requirement is for miniaturized, low cost, A/J antenna systems. The size of the antenna elements can be reduced using high-dielectric materials, allowing large arrays to be installed even on a small munition. Further improvements could also be achieved through the use of low noise or cryogenically cooled amplifier stages. High-speed A/D converters will permit sophisticated DSP algorithms and filters to be employed to achieve high J/S margins. Military development efforts should leverage the commercial advances in miniaturized electronics and signal processing and focus AF resources on A/J system design.

MEMS

Micro-electromechanical (MEM) inertial sensors can be fabricated by chemical etching of single crystal silicon or surface micromachining layers of polysilicon. Existing MEM sensors provide adequate performance for flight control, but are very low grade performers relative to navigation requirements. Future technologies that have the potential to improve the performance of MEM inertial sensors include Josephson Junction Gyros (JJG) which apply some properties of "high-temperature" superconducting materials to inertial sensing. Superconducting materials also offer the potential for significant improvements in the sensitivity of MEM accelerometers.

When integrated with GPS, a MEM IMU can provide an adequate autonomous navigation capability for short periods of time, for example in the presence of jamming. Significant advances

are required before MEM IMUs will approach the accuracy, for example, of an RLG INS system. The recommendation is to use commercial, low-grade MEM IMU technology and provide enhanced performance through GPS integration.

3.8 High Speed Signal Processing

Introduction

High speed signal processing is a basic technology whose emergence has been key to the increased capability of modern weapon systems. The technology area includes both commercial and special signal processing hardware and new signal processing techniques and algorithms. One example is expanding the current capability of LADAR seekers to do identification on large area targets and do precise aimpoint selection. Another is packaging of sufficient (4-5 Gflops) processing power in small volumes (< 6 cubic inches) with low power dissipation to do sensor fusion, automatic target recognition, and aimpoint selection from dual mode seekers on missiles to attack boost phase TBM's, low observable cruise, and air to air threat missiles. In addition, substantial parts reduction can be made in both RF and imaging systems with the development of high dynamic range, high slew rate A/D converters which can directly digitize the raw sensor signals. The development of advanced algorithms, including fast learning, self partitioning neural nets, image algebra, and data compression, implemented in special purpose chips will enable the autonomous acquisition and IFF functions to be performed with more robustness and with fewer parts in lighter weight packages requiring less power and packaging volume. A third area of advancing component technology for high speed signal processing is in integrated optics and hybrid optical correlation and processing. This device technology has promise to take advantage of the considerable higher parallel processing capability of optical components and the flexibility and versatility of digital processing to interface with missile guidance and control systems.

3.9 ECM Weapon Technologies

A description of the applicable ECM weapon technologies is given in the classified NWV report (see the Munitions Panel section).

4.0 Munitions Technology Integrating Concepts

Introduction

A munition system does not stand alone. It relies heavily on a myriad of technologies for its eyes (sensors), ears (information), structure (materials), energy (Directed Energy and Materials), overall mission planning (attack); and launch platform (aircraft and propulsion). The Munitions Panel has attempted to identify synergistic relationships between its sister NWV panels to help it invent munitions concepts which are deployable in the context of the NWV forecast technologies.

4.1 Unmanned Tactical Aircraft (UTA)

The unmanned tactical aircraft is a technology integrating concept in the 25+ years time frame. In terms of the *New World Vistas* tasking, the UTA integrates emerging technologies into an advanced warfighting capability that is consistent with the technology evolution in a broad spectrum of areas. The UTA integrates several munitions concepts broadly characterized as miniature munitions for precision strike.

4.2 Miniature Munitions

These concepts forecast enhanced warfighting capability in significantly smaller munitions packages than today's capability. The proposed lethality of these concepts suggests the integration of the capability into a platform concept which would provide independent targeting of munitions in the 50-150 pound category.

The purpose of developing this vision is to investigate the alternate planning approach which has been characterized as "back from the future". Its utility is the identification of missing technologies in the overall investment strategy that would expand the utility and range of applications of current investments. This integrating concept identifies a requirement for aircraft level dispensing systems that are compatible with the deployment of large numbers of small munitions which can be independently selected and targeted on command. This requirement is consistent with the current evolution toward internal carriage for enhanced stealth capabilities.

The vision for short range, air-to-air combat is to provide air superiority. This will be done by producing a small 100 pound missile as a replacement for Sidewinder (220 pounds). This new missile will be smaller, have the same warhead lethality, have the same range, but will have greater maneuverability (18°, off-bore sight capability). This will provide a weapons load-out of double today's number with a maneuvering missile. The payoff will more than double the kills per sortie because of load-out and the ability to protect from rear attacking aircraft or missiles. The technologies to enable this are cited below.

High Energy Density Materials

These new materials are feasible and many of them are already in development. Specific details are included in the Materials Panel report. In essence, propulsion energy improvements of 15%, with additional increases of 30% in mass fraction, are projected by the year 2010. This translates to payload increases of 100%. Similar improvements in warhead technology convert

to lethality enhancements, or overall miniaturization since there is an 8 to 1 leverage in payload weight to missile weight.

Thrust Magnitude/Vector Control

In order to get the required high maneuvering capability, the missile must have the kinematic ability to come off the rail with a first pulse (or motor burn operation) of low thrust with an effective vectoring system to turn the missile around. After turning, a second pulse of much greater propulsive magnitude is needed to complete intercept, with additional thrusting and vectoring capability needed in the end game for a hard-maneuvering target. Pulsing with solid propellant grain designs has been demonstrated. Other concepts (e.g., gel propellants, hybrids, pintels) are being investigated now and should be ideal for thrust magnitude control. Thrust vectoring is the subject of a current Wright Lab contract. It is a very feasible technology and is well-grounded in demonstrated jet tab, jet vanes, movable nozzles, and liquid injection in nozzle exit cones.

4.3 Advanced Stealth Weaponry

The context demands that we consider not only the observables and survivability features of the weapon, but also its carrier. If the carrier platform is assumed to either be stealthy in its own right and to be large enough to carry the weapon internally, thus avoiding carrier platform signature degradation, or if we assume that the weapon's range is such that the carrier can stand off outside the lethal radius of defending systems, then carrier/weapon LO integration issues may be minimized. The issue then is the observability of the weapon itself. The more stressing case, and the one most likely for future systems, involves carrier platforms that cannot afford to carry weapons internally and/or weapons that do not have sufficient range to assure the carrier is outside of lethal range.

The important post launch characteristics for the weapon are the same for both case - the weapon must find its way to the target while avoiding, or at least surviving encounters with, defender systems. This assumes that the weapon is of relatively high value to the attacker. A clear alternative is the use of numerous, relatively cheap weapons. This alternative could allow overwhelming the defense with multiple targets and forcing the defender to enter into an unfavorable draw down engagement. The level of stealth required for such weapons obviously would be less, or none. The remainder of this discussion assumes a relatively sophisticated, high value weapon that would employ aggressive signature reduction. Today's technology has proven adequate in most respects to accomplish this. In the case of some programs such as TSSAM, however, it appears that the affordability of such technology has not been conclusively established. Future efforts must find truly affordable technologies and designs to enable very aggressive signature management. They will need the ability to attack with impunity targets defended by large SAM systems such as the SA-10 and SA-12 and their successors.

For control of the RF signature the key technology enabler is low cost structures with good surface impedance control. This will allow for very aggressive signature control for weapon sized vehicles without resorting to the use of parasitic materials. Such materials are heavy, costly and require inefficient manufacturing methods. Low cost manufacturing methods are required to allow literally fabricating the entire outer structure and final surfaces using molding or other automated processes. Equally important are integrated airframe and propulsion systems.

Complicated serpentine inlet/exhaust systems must be replaced by systems that can allow illumination of the front and rear frames of the engine and still obtain acceptable observables performance. Inlet designs should be fixed, avoiding complex structure and seals. Advanced seal technology will be needed for maintaining signature control in areas where wings are folded forward for flight. Easily incorporating these seals into the airframe structure will be important. Again, low cost materials and assembly methods will be key enablers.

One key technology enabler for aggressive signature reduction lies not in materials or structures, but in weapon guidance and control. Achieving low signatures is made more difficult by the presence of apertures for seeker windows, antennas, etc. Solutions do exist but add significant complexity and cost to the system. Given very accurate navigation systems one can design weapons without seekers that can attack successfully all but the hardest of targets, or those whose precise location cannot be known at the time of weapon release.

Most of this discussion has dealt with areas affecting the higher frequency signature of a vehicle - the frequency where most threat systems operate. Lower frequency signature control may become more important in the future, especially if defenders employ low frequency radars that allow sufficient tracking accuracy to then utilize EO/IR seekers for the end game. Controlling low frequency response on the relatively small (electrically) structures of weapons is difficult using existing materials/methods. This points to key enablers in active and passive/active reduction methods.

For systems which are externally carried by the carrier platform the contribution of the weapon to the carrier's signature must be considered. Many alternatives have been put forward: shrouds to cover the weapon from some or all aspects, submerged carriage, blisters to cover the weapon, etc. Undoubtedly some of these concepts will be workable, especially for moderate levels of signature reduction. However, for aggressive levels it is difficult to employ such mechanical approaches and to assure carrier signature integrity both before and after weapon release. Active and/or active passive cancellation techniques may offer a solution. If the weapon could be integrated into the carrier's active control system, the total system signature could be managed so as to take account for the number of weapons and modified in real time as weapons are launched. The ultimate goal would be for weapons that could electrically become an integral part of the carrier's skin. The weapon would employ the same type of active/passive techniques as the carrier. The two would cooperatively adapt their surface impedances and currents in real time to essentially nullify the contribution of the weapon's signature. Once the weapon has been launched, the carrier's system would adapt to compensate.

The preceding discussion focuses on RF signature control. Future weapon applications must also consider EO/IR threats. We should expect that future threat systems will attempt to recover defended battle space area lost to stealth by exploiting other portions of the spectrum. EO/IR sensors are usually thought of as having limited utility because of their inability to deal with adverse weather conditions, including high humidity. They are also normally thought of as short range sensors. However, advances in sensor technology are increasing sensor sensitivity, and processing is improving the ability to detect low contrast targets. Large pixel count arrays using such technology are becoming commercially available at low cost, enabling affordable air defense systems employing large numbers of netted sensors. Both ground based and airborne (aircraft, UAVs, and aerostats) systems could proliferate in the future.

4.4 Multi Service Integration

The following concept offers a unique potential for multi-service integration and could have a very significant impact on deliverable firepower and cost.

Introduction

Historically, all three Services have tended to develop their own weapon systems. This situation was generally driven by Service unique requirements and compatibility with existing logistics trains and equipment. Although the Services are actively pursuing many common weapon systems, Service unique weapons will continue to exist for the foreseeable future. An attractive alternative to multi-Service weapon systems is to provide joint service operability. One approach is to incorporate in-flight retargeting capability. Long range strike weapons utilizing GPS/INS guidance would be particularly suitable. Weapons launched from virtually any platform could be directed as required by manned aircraft, UAVs, etc., to high priority targets or redirected away from a preplanned target to targets of immediate priority by simply updating target GPS coordinates. This capability could provide significant increases in fire power over what could be delivered by aircraft alone. By providing real time GPS updates in flight, GPS/INS guided systems could be used effectively against mobile targets. Aircraft would not be burdened with bulky strike weaponry but could instead carry primarily AAW weapons or uniquely time critical weapons and depend on surface, ship, or aircraft launched strike weapons to attack ground targets of interest. The proposed concept would require secure data links, embedded knowledge of missile performance envelopes, inflight redirection capability, and a flexible mission planning and coordination capability. Follow-on improvements could capitalize on the Navy s Cooperative Engagement Capability technology and include anti-air weapons.

Concept

This concept supports the need to Stop Invading Armies. The Air Force's surface strike capability is a key element in meeting this need. This mission area includes tactical interdiction, close air support, Suppression of Enemy Air Defenses (SEAD), etc. The surface strike mission is further subdivided into precision strike/ point targets and precision strike/ area or anti-materiel targets. Many of these targets are time critical and must be engaged during the early phase of war when platforms and weapons may be in short supply. This concept specifically addresses the following needs:

- Deliver the necessary fire power where required, when required: Each pilot could have at his command the available arsenal of Army, Navy, USAF, or USMC units within strike weapon range. This capability would substantially eliminate the need for an aircraft to carry its own strike weapons and the impact of this requirement on aircraft design and performance. Instead weapons from a variety of sources can be brought to bear on time critical targets when they are required. Sorties would not be limited by weapon loadout but by aircraft endurance.
- Reduce total costs per kill: Low cost GPS/INS guidance systems could be used against mobile targets by eliminating data latency induced errors in target location. Mobil target location could be updated real time to ensure data accuracy.

- Effectively utilize available assets, including Army, Navy, Air Force and Marine assets: During the early stages of war, only limited assets may be available for a given Service. By being able to utilize multi-Service assets, each Service could take advantage of the weapons available. In addition, the ability to utilize multi-Service assets without requiring common systems eliminates many of the difficult issues commonly associated with multi-Service use. Although product improvements to each of the systems will be required, the fundamental designs, and associated sunk costs in ancillary equipment will not be lost.

Enabling Technologies

There are several enabling technologies required to support this concept.

- Secure Data Links: Aircraft must be able to communicate with weapons inflight to provide redirection. This capability requires secure, robust data links which can be established rapidly and which provide the necessary bandwidth to transmit the required data within the time window required. Joint service data links and protocols may be a pacing issue.
- In-Flight Retargeting: Weapons will require the capability to receive secure, inflight target data, verify the redirection commands, verify the command authenticity, and execute the necessary guidance commands. This capability will require modifications to present missiles and common interfaces and protocols.
- Flexible Mission Planning and Coordination: Although efforts are underway to improve Joint Service Mission Planning, this concept requires the flexibility to accommodate fire redirections, account for the close proximity of aircraft and missiles, and require dynamic resource management to ensure missiles in the air when required. The companion concept for IFF, section 3.5, might provide not only IFF capabilities but also the necessary data base to support these requirements for flexible mission planning.

The concept of utilizing other Service weaponry could be extended to a variety of weapon types and missions. Implementation in GPS/INS guided long range strike systems could be only the first phase. This phase should resolve the issues cited above. Follow-on phases could address such missions as anti-air warfare. The Navy has recently demonstrated the capability for Cooperative Engagement. By merging these two capabilities, most of the technologies required for anti-air warfare would be resolved.

5.0 Conclusions and Recommendations

Identifying the Air Force's severest challenges to successful mission completion over the next several decades is both an exciting and an imprecise endeavor. However, we believe we have focused on those areas where improvements to weaponry can make substantial contributions to deterrence and allow the U.S. to prevail in future conflicts. Some of the technologies are here, others are just around the corner, and certain key ones await fundamental breakthroughs in materials or processes. But combined with creative approaches to weaponry design, all offer crucial enhancements to the Air Force warfighting capabilities.

Following are the Panel's assessment of the most important munitions concepts described in the report and recommendations, that will effectively implement these high payoff munitions that address future projected U.S. defense needs.

Airborne Interceptor (ABI)

A high velocity airborne interceptor missile system can be built today that could effectively intercept theater ballistic missiles during their boost/assent phase. This missile could also be the basis for other high velocity weapons that would dramatically increase the attack reach from an airplane or a UAV. It also has the potential to be expanded into a national missile defense capability. Finally, an ABI would generate participation by both the U.S. Navy and NATO allies in a joint program.

Recommendation

Conduct a detailed concept definition study focused on the ABI concept and technology descriptions in this report. Move ahead into system development.

ECM Cruise Missile

The increasing dependence of potential enemy armies, navies, and air forces on electronic systems for sensing, data processing, communication, and command and control make the nodes in these systems prime, high value targets. A stealthy cruise missile could be designed with an ECM technology warhead which would penetrate, attack, and shut down these targets.

Recommendation

Sponsor a multi-year technology demonstration of an ECM warhead that could be carried on a cruise missile and accomplish the tasks described in this report. (See classified NWV Volume - Munitions Panel Section).

Self Protection Missile (SPM)

Self protection of aircraft demands that new concepts be developed and integrated to provide the capability to intercept enemy air-to-air and surface-to-air missiles in both fighter and transport aircraft. A reaction driven projectile and a new small missile are the two concepts proposed.

Recommendation

Conduct a concept definition study that evaluates and selects between the concepts proposed: the reaction controlled projectile and a small, agile missile. A technology demonstration is needed for the reaction controlled projectile.

Autonomous Miniature Munitions (AMM)

The development of autonomous miniaturized munitions will significantly enhance interdiction, and stop invading armies. Small lightweight, high lethality, and great precision will increase the "pace" of warfare and multiply kills per sortie. Their ability to address a wide spectrum of target types will be a major asset in the implementation of dynamic battlefield management concepts.

Recommendation

- Emphasize systems which increase the "pace" of warfare by increasing the kills per sortie.
- Put together a miniature autonomous weapons program that will provide some near-term options and develop the technology base for the future.
- Conduct a technology demonstration of LOCAAS showing autonomous battlefield target detection, acquisition, and destruction of mobile targets.
- Pursue sensor and signal processing technology to improve target acquisition and classification. Establish specific milestones and address the expanded target spectrum.
- Design and demonstrate the capability to autonomously attack fixed or mobile targets.
- Set up a five year program culminating in a technology demonstration of powered flight for extended range of these miniature autonomous systems.

Hard Target Munitions

The ability to destroy hardened buried targets can be addressed with small, smart hard target weapons with enhanced velocity to enhance penetration. The smaller size weapon allows rapid reaction time, long range, increased flexibility and increased kills per sortie. It also provides a force multiplier for fighter and bomber aircraft as well as UAVs.

Recommendation

Conduct research to demonstrate a small (approximately 20 kg high explosive warhead) high velocity penetrator. The research plan must have specific milestones. The concept for delivery should be built around the hypervelocity missile developed for the ABI.

Enabling Technologies

As we developed our lists of capability needs and concepts, certain key enabling technologies and capabilities emerged. The following technologies and capabilities have such a wide range of applications and are so critical to the future missions of the Air Force that the Panel felt these should be specifically highlighted in our recommendations. However there are additional significant enabling technologies (see section 3.0) that warrant further consideration.

Recommendation

Create specific plans with milestones for the following evolving technologies:

- High energy explosives, i.e., a 60% increase in delivered energy;
- High specific energy controllable propellant, i.e., 15% increase;
- Plan for scramjet engine development.

Appendix A: Panel Charter

The Munitions Panel of the *New World Vistas* will identify new technologies and future weapon system concepts that will address in a swift and overwhelmingly decisive manner any threat posed to the United States. The panel must envision U.S. defense needs in the next 10 to 30 years, and craft future weapon systems that significantly enhance the U.S. Air Force capabilities to counter and dominate any hostility that threatens the U.S. interest.

The panel must assess pressing capability needs by reviewing the world current and future geopolitical and economic situations as they relate to national defense. The next requirement was to translate this environment in terms of generalized future military requirements and to identify pervasive, tough problems of most concern to the U.S. Air Force. The panel then needed to identify trade-offs of conventional wisdom evolutionary development versus potential paradigm shifts in conceptualizing future weapon concepts.

To realize the revolutionary munitions concepts developed, the panel was required to identify key enabling technologies and recommend specific actions to implement the proposed new weapon concepts.

Appendix B

Panel Members and Affiliations

SAB Members

Mr. Milton Finger, Chairman
Lawrence Livermore
National Laboratory

Dr. Robert W. Selden

Dr. Leonard (Buck) F. Buchanan
Point Loma Industries, Inc.

Dr. Alison K. Brown
NAVSYS Corp.

Executive Officers

Lt Col E. Van Davis
Air Combat Command

Lt Col David Hincy
USAF Scientific Advisory Board

Ad Hoc Advisors

Mr. Theodore W. Wong

Mr. J. Tom McMahan
Modern Technology Solutions, Inc.

Dr. Mike P. Shatz
MIT Lincoln Lab

Technical Editor

Lt Col Kurt Klingenberger
AF Education and Training
Command

U.S. Government Participants

Dr. Samuel C. Lambert
Wright Labs, Eglin AFB

Dr. Joseph C. Foster, Jr.
Wright Labs, Eglin AFB

Dr. Paul Jacobs
U.S. Army Missile Command

Mr. Danny L. Brunson
Naval Surface Warfare Center
Dahlgren

Dr. Robert C. Corley
Phillips Labs/Edwards AFB

Appendix C

Panel Meeting Locations and Topics

11-13 January	Eglin AFB, FL Workshop on small high yield munitions
27 January	Washington, D.C. High energy materials
3 March	Langley AFB, VA ACC perspective
22-23 March	Wright Patterson AFB, OH Wright Labs weapons and propulsion overview
28 March	Livermore, CA Precision strike
11-12 April	Washington, D.C. GPS/Inertial competent munition ACC perspective OSD perspective Aeroballistic Interceptor DoD wide terminal guidance R&D Quick response TBM counterforce
20 April	Kirtland AFB, NM Pervasive problems Paradigm shifts Enabling technologies Cross cutting underpinning S&T Kinetic energy
3-5 May	Maxwell AFB, AL Air Force revolutionary planning process Spacecast 2020 Less than lethal
22 May	Washington, D.C. Hypersonics
8 June	Kirtland AFB, NM Joint meeting with directed energy panel

6 July	Tucson, AZ (Hughes Missile) Technology enablers Battle damage assessment Hypersonic weapon system Smart munition concepts UAV hunter-killers Hypersonic mini SAR Wargaming
10-21 July	Newport Beach, CA Summer study

Appendix D

List of Acronyms

Acronym	Definition
A/D	Analog to Digital
A/J	Anti Jam
AAW	Anti Air Warhead
ABI	Airborne Interceptor
ACM	Advanced Cruise Missile
ADN	Ammonium Dinitramide
AFB	Air Force Base
AIM-9	Sidewinder Air-to-Air Missile
AIT	Atmospheric Interceptor Technology
AL	Aluminum Metal Powder
AMM	Autonomous Miniature Munitions
AMRAAM	Advanced Medium Range Air-to-Air Missile System
AP	Ammonium Perchlorate
APT	Acquisition Pointing and Tracking
ATACM	Advanced Tactical Army Combat Missile System
ATR	Automatic Target Recognition
AWACS	Airborne Warning and Control System
BDA	Bomb Damage Assessment
BECO	Booster Engine Cutoff
BLU	Bomb Laser Unit
BMDO	Ballistic Missile Defense Organization
C^3	Command, Control, Communications
CAP	Combat Air Patrol
CAD	Computer Aided Design
CAM	Computer Aided Manufacturing
CCM	Counter-Countermeasures
CEP	Circular Error of Probability

Acronym	Definition
CL-20	Hexanitrowurzitane
CVN	Aircraft Carrier
DMZ	Demilitarized Zone
DoD	Department of Defense
DOI	Direct Optical Initiation
DSP	Defense Satellite Program
DTED	Digital Terrain Elevation Data
ECM	Electronic Countermeasure
ECCM	Electronic Counter-Countermeasures
EDGE	Exploitation of Differential GPS for Guidance Enhancement
EMD	Engineering, Manufacturing Development
EO	Electro-optical
ERINT	Extended Range nterceptor
FAA	Federal Aviation Adminsitration
FPA	Focal Plane Array
GBU	Glide Bomb Unit
GIS	Graphic Information System
GPS	Global Positioning System
HARM	High Speed Anti Radiation Missile
HE	High Explosive
HEDI	High Endoatmospheric Defense Interception
HEDM	High Energy Density Materials
HIPEN	High Velocity Penetration Weapon
$KClO_4$	Potassium Perchlorate
HMX	Cyclo Tetramethylene Tetranitramine
HOE	Homing Overlay Experiments
ICBM	Intercontinental Ballistic Missile

Acronym	Definition
IFF	Identify Friend or Foe
IM	Insensitive munitions
IMU	Inertial Measurement Unit
INS	Inertial Navigation System
IR	Infrared
IRFPA	Infrared Focal Plane Arrays
IRST	Infra Red Search and Track
J/S	Jam Suppresion
JDAM	Joint Direct Attack Munition
JJG	Josephson Junction Gyros
JSTARS	Joint Surveillance, Tracking and Reconaissance
KKV	Kinetic Kill Vehicle
LADAR	Laser Detection and Ranging
LEAP	Lightweight Exoatmospheric Projectile
LIDAR	Light Detection and Radar
LO	Low Observable
LOCAAS	Low Cost Anti-Armor Submunition
LPI	Low Probability of Intercept
LWIR	Long Wave Infra Red
MoO_3	Molybdenum Trioxide
MCM	Multi Chip Module
MEMS	Micro Electro-Mechanical Systems
MERS	Multiple Ejector Rack System
MHIP	Missile Homing Improvement Program
MIC	Metastable Interstitial Composites
MS	Milliseconds
MWIR	Mid Wave Infra Red

Acronym	Definition
NBC	Nuclear, Biological, Chemical (Weapons)
PAC-III	Partiot System Upgrade
PPI	Planned Product Improvement
PK	Probability of Kill
PSSK	Probability of Single Shot Kill
RCS	Radar Cross Section
RDX	Cyclo Trimethylene Trinitramine
RF	Radio Frequency
RV	Rentry Vehicle
SAM	Surface to Air Missile
SAR	Synthetic Aperature Radar
SDI	Strategic Defense Initiative
SEAD	Suppression of Enemy Air Defense
Sidewinder	Aim 9, Air-to-Air Missile
SPM	Self Protection Missile
SSHTW	Smart Small Hard Target Weapon
TAD	Tactical Munitions Dispenser
TBM	Theater Ballistic Missile
Teflon	Tetrafluoroethylene Polymer
TERCOM	Terrain Contour Matching
TERS	Triple Ejector Rack System
THAAD	Theatre High Altitude Area Defense
TMC	Thrust Magnitude Control
TMD	Tactical Munitions Dispenser
TSSAM	Triservice Standoff Attack Missile
TVC	Thrust Vector Control

Acronym	Definition
UCAV	Unmanned Combat Air Vehicle
UAV	Unmanned Air Vehicles
USAF	United States Air Force
USN	United States Navy
UV	Ultraviolet
WMD	Weapons of Mass Destruction